REPORT

ON

WATER PURIFICATION INVESTIGATION

AND ON

PLANS PROPOSED

FOR

SEWERAGE

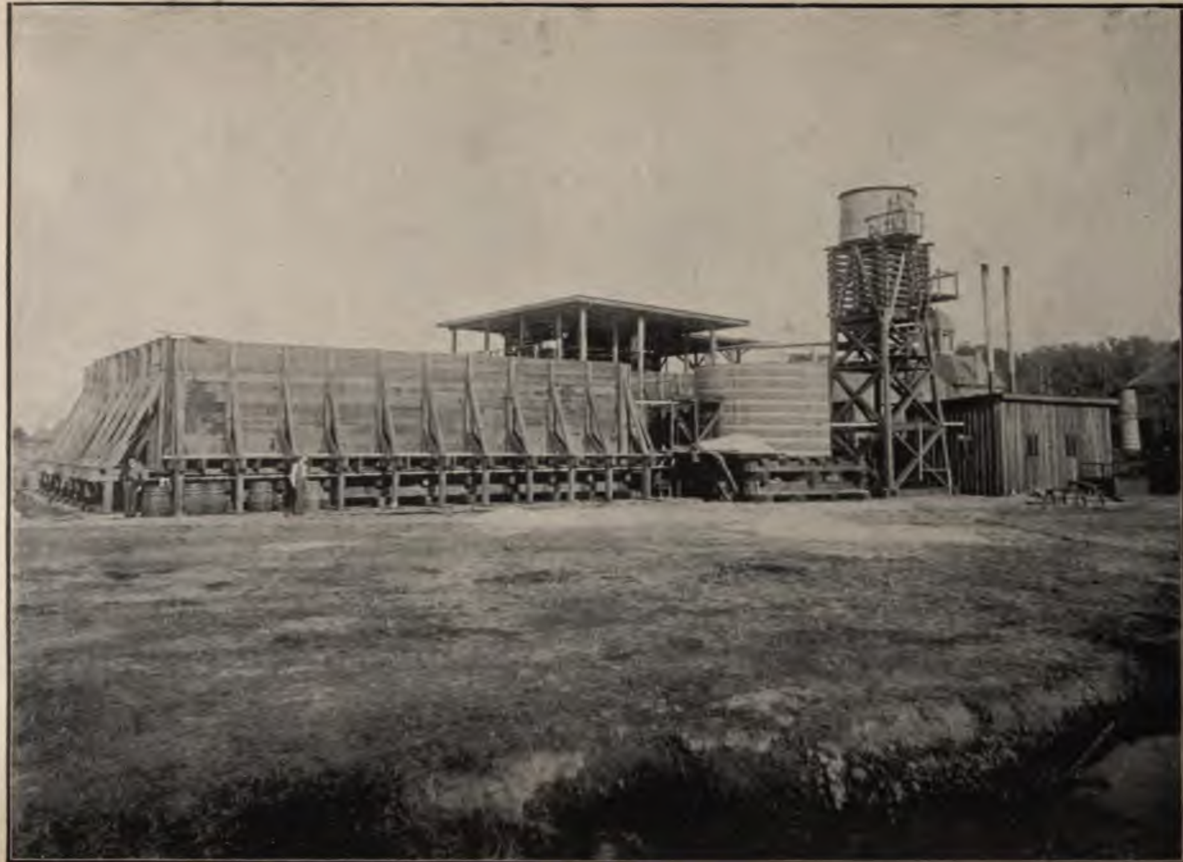
AND

WATER-WORKS SYSTEMS

SEWERAGE AND WATER BOARD,

NEW ORLEANS, LA.

1903



GENERAL VIEW OF PURIFICATION STATION.

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SEWERAGE AND WATER BOARD, 1903
NEW ORLEANS, LA.

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AND

WATER-WORKS SYSTEMS

JANUARY 1st, 1903.

NEW ORLEANS:
A. W. HYATT STATIONERY MANUFACTURING CO., Ltd., 407 CAMP STREET.
1903

TABLE OF CONTENTS.

CHAPTER II.

Description of Water Purification Station.

CHAPTER III.

MANNER OF OPERATION OF THE PLAIN SUBSIDING BASINS, AND THE EFFICIENCY OF PLAIN SUBSIDENCE FOR VARIOUS PERIODS IN THE CLARIFICATION AND PURIFICATION OF THE RIVER WATER.

CHAPTER IV.

DESCRIPTION AND RESULTS OF THE OPERATION OF THE ENGLISH FILTER NO. 1 AND DISCUSSION OF THE LEADING FEATURES ASSOCIATED THEREWITH.

CHAPTER V.

DESCRIPTION OF THE OPERATION OF THE MODIFIED ENGLISH SYSTEM OF WATER PURIFICATION AND DISCUSSION OF THE LEADING FACTORS ASSOCIATED THEREWITH.

CHAPTER VI.

DESCRIPTION OF THE OPERATION OF THE AMERICAN SYSTEM, AND DISCUSSION OF THE LEADING FEATURES ASSOCIATED THEREWITH.

CHAPTER VII.

FINAL RESUMÉ AND CONCLUSIONS.

CHAPTER VIII.

CHAPTER IX.

OUTLINE OF PLANS PROPOSED FOR SEWERAGE AND WATERWORKS SYSTEMS.

CHAPTER X.

THE PROPOSED SEWERAGE SYSTEM.

LIST OF PLATES.

WATER PURIFICATION INVESTIGATION.

PLANS FOR PROPOSED SEWERAGE AND WATERWORKS SYSTEM.

LIST OF TABLES.

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* Died November 15, 1901.

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LABORATORY.

(Subsequent to January, 1902.)

JOHN L. PORTER..Chemist.
LEO FUERST..Clerk.

WATER PURIFICATION INVESTIGATION.

(Prior to January, 1902.)

R. S. WESTON...Resident Expert.

The force employed under Mr. Weston's direction will be found on page 10.

INTRODUCTION AND TRANSMISSION TO SEWERAGE AND WATER BOARD.

NEW ORLEANS, January 1st, 1903.

To the Honorable President and Members of the
Sewerage and Water Board:

GENTLEMEN—Since the report herewith presented will be the first of considerable technical interest issued by the Sewerage and Water Board, and will be quite widely distributed, it has seemed best that there should be included in it, not only the account of the water purification investigation, but also enough plans and descriptive text to give those who receive it a general idea of the ultimate water purification plant which it is proposed to construct, and also of the whole work with which the Sewerage and Water Board is charged.

Chapters I to VIII, inclusive, contain Mr. R. S. Weston's report on the water purification investigation.

Following Mr. Weston's report will be found a report by Messrs. Herring and Fuller, of your Advisory Board of Engineers, briefly reviewing the water purification problem.

The engineering work leading up to the plans for sewerage and water works systems, as now proposed, has been carried forward continuously from June, 1900, to present time, and the main features of the results accomplished will be found in chapters X and XI.

Chapter X is by Mr. W. T. Crotts, whose efficient services in connection with the sewerage work for the past two years cannot be too highly commended.

This chapter contains such descriptive matter with regard to the proposed sewerage system as will be of general interest.

Chapter XI is by the writer, and treats of the proposed water works system, giving a brief description of the proposed work, and of the causes which have dictated the existing plans.

In connection with the water purification investigation a very brief historical review of the pertinent facts leading up to the investigation will show that the Sewerage and Water Board gave careful and deliberate consideration to the question of the necessity and wisdom of making such an investigation, and when once that was satisfactorily shown, the authority was promptly granted by the Board and the execution in the hands of the Sewerage and Water Committee was expeditious.

The first suggestion of the necessity for such an investigation came from your General Superintendent in his preliminary report in February, 1900. In April, 1900, there was an extended report made upon the question of water purification in other American cities, again stating the necessity for a thorough investigation into this question for New Orleans.

Early in June, 1900, the Advisory Board of Engineers held its first meeting, and evidence presented to them by the General Superintendent showed quite conclusively that the cost of a complete water works system for New Orleans would be about doubled if any source other than the Mississippi were chosen, and that the available resources in the hands of the Board were not only too small for the serious consideration of the adoption of any outside source of supply, but that they were likely to be too small even for the immediate completion of the cheaper system of water works and of the sewerage system within the populated area.

Under these circumstances they recommended sufficient further investigations of outside sources to make certain that the facts were really as above stated in connection with such sources, and they also recommended that an investigation be made to determine the cheapest and most efficient method of purifying the Mississippi River water; they further recommended that such investigation should be undertaken at once, and should extend through a period of one year. Mr. Geo. W. Fuller, member of Advisory Board and an expert in water purification, outlined the general scope of the investigation which he considered essential, and estimated its cost at about $20,000.

When this recommendation was first brought to the attention of the Sewerage and Water Board it was not received with immediate approbation. It was argued that the New Orleans Water Works Company had tried filtration in 1892, that this trial had proved to be a very expensive failure, and that there seemed little chance for the Sewerage and Water Board to succeed by the expenditure of $20,000 where this other effort had failed, despite the expenditure of many times that amount. A full and detailed report was, however, demanded of the General Superintendent, and was submitted to the Board in July, showing the present status of water purification, the causes which led to the failure of the Water Works Company's efforts in this direction, the position of several other cities in this connection, and how properly conducted investigations had brought to them satisfactory solutions of equally difficult and somewhat similar problems, the methods by which scientific and successful purification systems had been developed elsewhere, and, finally, what had to be learned for New Orleans, how this knowledge was to be obtained, how it would apply in solving the local problem and how much it would cost.

Having received the information above outlined and seeing clearly the necessity which existed for such an investigation, it was authorized in August of 1900, and placed under the supervision of the Sewerage and Water Committee. Meantime, plans for the required plant had been worked out, and, as soon as a site for the plant could be chosen, a contract was awarded for its construction.

Work was started early in September, and a little later, Mr. R. S. Weston, Resident Expert, arrived in New Orleans and took personal charge of the laboratory equipment and detailed fitting out of all parts of the work with such good results that the basins, filters, etc., were put into operation on 15th of December, and the plant run thereafter continuously to the close of the investigation in August, 1901.

Too much credit cannot be given to Mr. Weston for his industrious, economical and efficient administration of this work, and the little force under him attended to its multiplicity of duties with a faithfulness worthy of the highest praise.

Both Mr. Fuller and your General Superintendent received two reports each month giving in detail all results obtained. Mr. Fuller was in constant touch through correspondence and made several special visits to this work. Your General Superintendent visited the plant frequently, and was in close personal touch with the whole investigation.

The Sewerage and Water Committee, either as a whole or through its individual members, made several inspections of the plant, and the method of operation.

The site chosen for the investigation was in Audubon Park, a favorite resort for the people of the city; the choice of this site was made because it was desired that as many people as possible should have an opportunity to inspect the plant in operation, and it is pleasant to note that visitors were numerous, interested and pleased with the promise of a clear, pure water supply which the effluent from three of the four systems there in operation never failed to yield.

In considering the question of purification of Mississippi River water, in his preliminary report, your General Superintendent said, in substance, that the history of efforts and experiments in the successful purification of such water, thus far, seems to point toward the following method, viz: plain subsidence for a period of not less than forty-eight hours in reservoirs operated on the fill and draw plan (which would require reservoirs holding considerably more than forty-eight hours' supply), then the addition of coagulant, followed by a short period of auxiliary subsidence, then mechanical or rapid filtration by gravity through sand filters.

It will be noted that all of the essential operations were correctly forecasted, but the relative and total times for plain subsidence and auxiliary subsidence after coagulation were very far from the final solution which the investigation has brought. We would not have dared design a large system on nearly so short a time as twelve hours of plain subsidence, nor would we probably have considered so long a period as twelve hours of auxiliary subsidence. The effect, therefore, of the investigation is to cut down the first cost of the required purification plant by many times the cost of the investigation, and to increase efficiency and decrease greatly the cost of annual operation as compared with what must have followed any other design than that which the investigation has indicated as the most efficient and economical.

In concluding this introductory chapter, the writer wishes to acknowledge with gratitude the faithful, willing and efficient work of all of the men under his direction in the Engineering Department of the Board during the two years of preliminary work just passed; his thanks are also due to the efficient Secretary of the Board, Mr. F. S. Shields, for his helpful co-operation in every matter where his experience, good judgment and willing aid could possibly forward the interests of the Board.

Respectfully submitted,

GEO. G. EARL.

General Superintendent.

WATER PURIFICATION REPORT.

INTRODUCTORY.

MR. GEO. G. EARL,

General Superintendent, Sewerage and Water Board of New Orleans:

SIR:—Regarding the investigations at the Water Purification Station, the writer has the honor to present the following report:

OBJECT OF WORK.

In June, 1900, the Board of Advisory Engineers passed the following resolution:

"*Resolved*, That it is the judgment of the Board of Advisory Engineers that the water of the Mississippi river, in the vicinity of New Orleans, can be purified in a thoroughly satisfactory manner and at a total cost within reasonable limits; that accurate information is now lacking concerning the range in amount and character of matters suspended in the water; that purification works cannot now be designed in detail consistent with needed economy; that it is, therefore, recommended that the General Superintendent be authorized to conduct, continuously, a series of investigations upon these points for a period of one year; and that such preliminary work should be begun as soon as practicable so that it will not delay the completion of the entire system of sewerage and water supply."

On July 19th, 1900, the Sewerage and Water Board passed the following resolution:

"Both for the purpose of carrying into effect Resolution No. 8, and also more fully the provisions of Resolution No. 7, the General Superintendent, with the consent and approval of the Committee on Sewerage and Water, and in accordance with the provisions of Section 13 of the Sewerage and Water Act (No 6), be authorized to employ skilled and ordinary labor, and contract for or purchase all the tools and material unavoidably required for conducting and executing the work of experiment as recommended, at a total cost not to exceed $20,000 for materials and labor of all kinds, employed in such experiment, all of said expenditure to be first authorized and approved by the Committee on Sewerage and Water."

This fund of $20,000 was expended by June 1st, 1901, and, in order to continue the investigations, the Sewerage and Water Board passed the following resolution:

"*Resolved*, That in compliance with the report and recommendation of the Committee on Sewerage and Water, the water purification investigation now being prosecuted at the Audubon Park Station, be continued to its ultimate satisfactory completion and the compilation of the necessary reports, at a cost on the average not exceeding $1000 per month, for a period not to exceed four months from June 1st, proximo."

Doubtless a purification plant could have been designed on the basis of the results of the investigations at Louisville, Pittsburg and Cincinnati, but the available evidence was not definite enough to accurately determine how large the subsiding basins should be built, in order to provide a period during which the clay, silt and coarser particles of the river water could be most efficiently and economically removed by plain subsidence. Again, there was equal uncertainty regarding the size of the basins in which the water would have to be further clarified at times of muddy water, by the use of a coagulant and thus properly prepared for advantageous filtration. From this it may be understood that the uncertain elements in adapting a design to successfully cope with the peculiar local problems were ones which markedly affected the cost of installation, due to the expense of basin construction. In solving these problems there was, of course, opportunity to carefully study the adjustment of a number of other phases of the processes to the local conditions, as well as to collect more definite information about the character of the Mississippi River water at various stages.

GENERAL DESCRIPTION OF THE WATER PURIFICATION STATION.

The Water Purification Station was located at Audubon Park. It had a capacity of 93,000 gallons of water per day, or enough to supply about 1,000 people. In a few words, the plant consisted of the following structures:

1. An intake, pump and force main, to supply water from the river to the station.
2. Four complete systems of water purification, on a small scale, each consisting of a filter, subsiding basin, and, in three out of four cases, a coagulating basin.
3. A water supply, for use in washing the filters, and also to supply water to the laboratory and boilers.
4. A boiler house, containing two boilers, work bench and storage room for tools, supplies, etc.
5. A laboratory building, of cheap construction, equipped with sufficient and necessary apparatus and supplies to allow the necessarily numerous and complete chemical and bacterial analyses to be made.

Besides the above, the plant was equipped with the necessary valves, meters, gauges and other devices and tools, both for its operation and for a careful record thereof. Most of the filtered water was discharged into a pipe leading to the Audubon Park wading pool.

MODIFICATIONS OF THE WATER PURIFICATION PLANT.

As the work progressed, the results clearly indicated that certain modifications in the schedule of operations should be made. These changes were as follows:

1. During April, it was decided to modify the subsiding and coagulating basins so that only those data might be obtained which previous results had indicated would be of most practical value.

2. In July, arrangements were made to supply filter No. 2 with the effluent of subsiding basin No. 1. In order to do this, it was necessary to shut down filter No. 1.

Besides the above, several minor changes and improvements were made from time to time to facilitate the operation of the plant or the study of special problems.

PERIOD OF INVESTIGATION.

The writer was engaged as Resident Expert on September 8th, 1900, arriving in New Orleans on September 21st, to take charge of the investigations under the joint direction of the General Superintendent and Mr. Geo. W. Fuller the member of the Board of Advisory Engineers, especially concerned with the water purification problems. Plans were drawn for the basins and buildings (with the exception of the laboratory and boiler house), and contracts were let for the same just before the writer took active charge of the work. The construction of the Water Purification Station occupied the months of October, November, and the first half of December.

On December 15th, the plant was put into regular operation. It ran continuously until August 17th, 1901. A portion of the plant has been kept in operation since August 17th, in order to supply the Audubon Park wading pool with filtered water.

AMOUNT OF ANALYTICAL WORK.

The following amount of analytical work was accomplished in order to determine the character of the water, before and after treatment, in the four purification systems, thereby making a record of the efficiencies of the same:

Number of complete analyses	387
Number of "suspended matter" determinations	1,050
Number of "silica turbidity" determinations	8,995
Number of mineral analyses	20
Number of quantitative bacterial analyses	8,878
Number of tests for Bacillus coli communis	100
Number of tests for Bacillus enteritidis sporogenes	29
Number of microscopical analyses	8

Besides the above, special analyses were made of the filter sands, basin sediments, sulphate of alumina, etc. A careful study of the flora of the river was also made and nine previously undescribed species of bacteria were isolated.

FORCE EMPLOYED.

The regular force of trained assistants consisted of four men, besides the writer, as follows:

Mr. John L. Porter, - - -	Assistant Chemist.
Mr. J. Beasley Perkins, / Mr. O. C. Reppel,	Assistant Chemist.
Mr. Alexander Allison, Jr., / Mr. Edward A. Fowler, / Mr. W. L. Raymond,	Engineering Assistant.
Mr. Andrew Allison, - - -	Assistant Biologist.

Mr. Perkins resigned on July 1st on account of ill health. Mr. Reppel was appointed in his place. Messrs. Allison, Fowler and Raymond were all in the employ of the Board. One or another of these gentlemen was employed at the Water Purification Station. Mr. Allison, during the period of construction, and Mr. Fowler, during the period of operation, except during a short sick leave when Mr. Raymond took his place.

Besides the above, there were two filter attendants and two firemen; and mechanics and laborers were employed for the construction, alteration and repairing of the plant.

The writer wishes to thank his staff of assistants for their faithfulness and devotion to the work, the success of which was largely due to their efforts. He wishes to thank the General Superintendent for his interest, advice and co-operation, all of which were very important factors in carrying on the work. He wishes to thank the Secretary for the advice and assistance which he has freely given. He also wishes to thank the Assistant Engineers of the Board, Mr. Adam Wirth, City Chemist, and Messrs. Kendall and Fuerst, students in the laboratory, also Dr. Stubbs, of the Louisiana Experimental Station, and the U. S. Engineer officers stationed at New Orleans for important help rendered at various times.

The general policy of the investigation was shaped only after consultation with Mr. Geo. W. Fuller, of the Advisory Board. This was effected both by correspondence and by five personal consultations as follows:

1. In New York, September 17th and 18th, 1900.
2. In New Orleans, December 14th and 15th, 1900.
3. In New Orleans, April 10th to April 13th, 1901.
4. In New York, June 21st and 22d, 1901.
5. In New Orleans, July 30th and 31st, August 1st, 1901.

These consultations were indispensable factors in carrying out the work, besides being exceedingly agreeable and profitable to the writer.

COST OF INVESTIGATION.

The cost of the Water Purification Investigation up to October 1st, 1901, is as follows:

Building and settling tanks	$5,734 76
Filters and clear water tanks	1,327 75
Pipes and fittings and tools	1,808 65
Boilers and machinery	722 50
Extra labor	1,521 41
Freight and drayage	241 90
Laboratory apparatus	2,298 12
Pay roll	7,640 41
Coal, supplies and miscellaneous expenses	2,115 35
Insurance	120 00
Repairing roadway in Audubon Park	75 00
	$23,605 85

BRIEF OUTLINE OF REPORT.

The report begins with a description and a record of the character of the Mississippi River water at New Orleans, together with the meteorological data which are logically connected therewith. Then follows a condensed description of the Water Purification Station, illustrated with drawings and photographs. Next, there is a description of the operation of the subsiding basins, and after that comes a description and discussion of the operation of the three coagulating basins receiving subsided water, and the four filters. The report ends with an untechnical resumé of the conclusions deduced from the investigation.

The report is divided into seven chapters, which contain the main results of the investigation. Some of the more detailed results, however, are given in the appendices. The list of chapters is as follows:

LIST OF CHAPTERS.

CHAPTER I.

Composition and Character of the Mississippi River Water.

As this report has to do with the purification of the Mississippi River water, it is essential that the composition and character of the water with which a purification system would have to do should be understood as thoroughly as the data at hand will allow.

MOST CHARACTERISTIC FEATURES OF THE MISSISSIPPI RIVER WATER.

The Mississippi River is a clay-bearing stream whose water, at New Orleans, possesses many characteristic features, chief among which are the following:

1. The wide variation in the amount of suspended matter. This variation is not so wide, however, as in the case of many of the tributaries.
2. The comparatively large proportion of the suspended matter, which is made up of fine clay particles.
3. The absence of sudden changes in the amounts of suspended matter in the water.
4. The frequent but not sudden changes in the character of the water, due to the predominance of one or another of the tributaries.
5. The absence of appreciable evidences of sewage contamination. This is because of the great dilution of the sewage entering the stream, the remoteness of the sources of pollution, and the almost complete purification effected in the river itself by natural agencies, during the stream's passage through the delta, the surface of which drains away from instead of into the river.

VARIATIONS IN THE TURBIDITY OF THE CROSS-SECTION OF THE STREAM.

It was very important to know how closely the water which was taken from the river during these investigations represented the average water of the river. The intake of the Water Purification Station was located on a making bank, while the proposed intake for the new purification plant is to be located on a caving bank. Observations by Humphrey & Abbott* and others go to show that the amounts of suspended matter contained in the river increases somewhat with the depth below the surface. Observations during this investigation indi-

*Report on the Mississippi River—1861.

cate that this is more evident during a rising than during a falling stage of the river, as the following data will illustrate, the results of which are expressed in parts per million.

Two sets of observations were made; one during a rising, and one during a falling stage of the river.

TABLE I.

First Observations—April 1st, 1901.

Stage of the river: 9.5 feet and rising slowly.
Turbidity of the water at the Station intake: 850 parts.

Upper End of a Making Bank at Nine Mile Point.

Distance from Shore.	Depth below Surface.	Silica Turbidity.*
0 feet.	0 feet.	810 parts.
25 feet.	5 feet.	750 parts.
50 feet.	8 feet.	900 parts.
100 feet.	0 feet.	900 parts.
100 feet.	24 feet.	875 parts.
200 feet.	0 feet.	875 parts.
200 feet.	25 feet.	875 parts.
200 feet.	50 feet.	875 parts.

Middle of a Straight Reach near Coalport.

Distance from Shore.	Depth below Surface.	Silica Turbidity.
0 feet.	0 feet.	800 parts.
40 feet.	0 feet.	975 parts.
40 feet.	6 feet.	975 parts.
80 feet.	0 feet.	925 parts.
80 feet.	9 feet.	975 parts.
100 feet.	0 feet.	975 parts.
100 feet.	15 feet.	975 parts.
160 feet.	0 feet.	925 parts.
160 feet.	30 feet.	1075 parts.

* For explanation of "silica turbidity," see page 24.

No sub-surface samples could be taken opposite the caving bank at Carrollton on account of the swiftness of the current; surface samples contained 850, 800, 875 and 800 parts of turbidity, respectively.

TABLE II.

Second Observations—July 24th, 1901.

Stage of the river: 2.8 feet and falling slowly.
Average turbidity of the water at the Station intake: 375 parts.

Upper End of a Making Bank at Nine Mile Point.

Distance from Shore.	Depth below Surface.	Silica Turbidity.
0 feet.	0 feet.	275 parts.
25 feet.	0 feet.	200 parts.
25 feet.	25 feet.*	550 parts.
100 feet.	0 feet.	250 parts.
100 feet.	50 feet.	360 parts.

Middle of Reach opposite the Proposed Intake.

Distance from Shore.	Depth below Surface.	Silica Turbidity.
0 feet.	0 feet.	260 parts.
50 feet.	0 feet.	360 parts.
50 feet.	45 feet.*	575 parts.
100 feet.	0 feet.	375 parts.
100 feet	25 feet.	350 parts.
100 feet.	50 feet.	325 parts.

* (Near bottom.)

Caving Bank above Southport Docks.

Distance from Shore.	Depth below Surface.	Silica Turbidity.
0 feet.	0 feet.	250 parts.
25 feet.	0 feet.	300 parts.
50 feet.	25 feet.	375 parts.
75 feet.	0 feet.	275 parts.
75 feet.	25 feet.	325 parts.
75 feet.	50 feet.	350 parts.
150 feet.	0 feet.	300 parts.
150 feet.	50 feet.	375 parts.

The following table shows the results in a more compact form:

TABLE III.

Table Showing the Relative Turbidities of Samples of Mississippi River Water, taken Opposite Different Types of Banks, and at Different Depths.

Source of Sample.	Average Turbidity—Parts per Million.					
	Surface.		Middle Depths.		Near Bottom.	
	April.	July.	April.	July.	April.	July.
Making Bank.........	860	260	850	360	940	550
Straight Reach......	920	330	975	340	1025	575
Caving Bank..........	850	280	....	350	....	350
Mid Stream............	850	290	....	....	....	....

As the end of the intake of the Water Purification Station was suspended from a house-boat in the middle depths of the stream, it would seem that water of about the average composition was supplied to the purification plant. This is believed because the observations show that water drawn from a point midway between the surface and the bottom is fairly uniform, whether the sample is taken from near a making or a caving bank or a straight reach.

The practical significance of these observations is, that in order to get the clearest water, an intake should be located at the surface of the river.

DESCRIPTION OF THE WATER-SHED.

The water-shed of the Mississippi River has an area of about 1,240,000 square miles. Naturally, such a large water-shed exhibits great variations in the amounts of rainfall, geological formation and climate, therefore, great differences in the character of the many tributaries of the great river which drains it.

While it is not within the province of this report to describe the water-shed in detail, there are certain features which must be mentioned because they affect the character of the Mississippi River water at New Orleans.

The water-shed area includes eleven States and Territories and parts of twenty others; also a part of Canada. It is very easy to comprehend the diversity in the character of the river which flows by New Orleans when one considers that within the Mississippi Basin are the slopes of the Alleghanies and the Rockies; the lakes of New York, Minnesota and the Far West; the limestone forming country of Kentucky and Tennessee, and the black bottoms of the Dakotas; the fertile plains of the Central West and Colorado, and the swamp lands of the Central Valley itself.

The drainage basin of the river embraces six great natural divisions, as follows:

The Ohio Basin,
The Upper Mississippi Basin,
The Missouri Basin,
The Arkansas Basin,
The Red Basin, and
The Central Valley.

The following table shows the area of each division and the ratio which its size bears to the size of the whole Basin:

TABLE IV.

Areas of the Principal Basins.

Basin.	Area.	
	Square Miles.	Percentage of Total.
Ohio	201,700	16
Upper Mississippi	165,900	13
Missouri	527,150	43
Arkansas	186,300	15
Red	90,000	07
Central Valley	69,000	06
Total	1,240,050	100

The discharges of the tributaries, however, do not vary directly with the sizes of the water-sheds, because of the great differences in the amount of rainfall in the different sections. For example: The Missouri basin, which receives the least downpour, has the largest area.

The following table shows the amount of annual rainfall in the various river basins, the figures being taken from the records of the U. S. Weather Bureau:

TABLE V.

Annual Rainfall in River Basins.

BASIN.	Inches per Year.
Ohio	44.2
Upper Mississippi	31.9
Missouri	19.4
Arkansas	29.6
Red	39.1
Central Valley	51.5
Entire Mississippi	29.8

The following table illustrates the relative stream discharges, areas and rainfalls for the various basins, the quantities varying with the values of the figures:

TABLE VI.

Showing Relative Stream Discharges, Area and Rainfall for the Various Basins.

BASIN.	Stream Discharge.	Area.	RAINFALL.
Ohio	1	2	2
Upper Mississippi	4	4	4
Missouri	3	1	6
Arkansas	5	3	5
Red	6	5	3
Central Valley	2	6	1

The waters of the various tributaries of the Mississippi vary greatly in composition since they drain areas which differ in their characters.

The data in the following table, although incomplete and not directly comparable, will serve to illustrate these variations:

TABLE VII.

Illustrating Differences in the Analytical Character of Tributaries of Mississippi River Water.

Tributary	Ohio.	Ohio.	Allegheny.	Tennessee.	Mississippi.	Red.	Missouri.	Mississippi.
Locality	Louisville.	Cincinnati.	Pittsburg.	Knoxville.	Minneapolis.	Shreveport.	St. Louis.	Quincy. Ills.
Turbidity—Silica Standard	420	275	66	250	7	...	...	143
Color—Hazen's Standard	15	15	28	...	43	...	...	71
Nitrogen as Albuminoid Ammonia Total	370	.290	.128	...	.190	...	...	.458
Nitrogen as Albuminoid Ammonia Suspended	.280	.200	...	...	.023	...	...	.203
Nitrogen as Free Ammonia	.044	.025	.018	...	.014	...	...	.004
Nitrogen as Nitrites	.008	.003	.000	...	.005	...	...	.014
Nitrogen as Nitrates	.77	.60	.61	...	.10	...	...	.36
Chlorine	17.	10.	22.6	...	.32	...	15.	6.3
Incrusting Constituents	18.	33.	9.	...	0.	240.	...	13.
Alkalinity	65.	45.	31.	50.	142.	120.	...	90.
Residue on Evaporation Total	500.	350.	190.	456.	209.	...	...	293.
Residue on Evaporation Suspended	350.	230.	55.	375.	9.	...	987.	126.
Residue on Evaporation Dissolved	150.	120.	135.	71.	200.	...	...	167.
Carbon dioxid (free and half bound)	70.	26.	...	...	...	...	...	5.8
Authority	Fuller.	Fuller.	Hazen.	Soper.	Weston	Weston	Whitman.	Ellms.

NOTE.—In estimating the silica turbidities of the waters in other localities the turbidity coefficient of 1.20 has been assumed.

The urban population of the Valley is estimated to be about 9,000,000, including all towns which have 4000 or more population,

as determined by the census of 1900. The division of the population by basins is given in the following table:

TABLE VIII.

Urban Population of the Great Divisions of the Mississippi River.

BASIN.	Urban Population, 1900.
Ohio	3,315,078
Upper Mississippi	3,117,655
Missouri	1,076,152
Arkansas	327,718
Red	103,052
Central Valley	892,170

Of this total population, 15,374 live in Louisiana, 86,335 in Arkansas, 39,620 in Mississippi, and 116,831 in Tennessee, therefore, the urban population of these States, in so for as their areas lie within the Mississippi Basin, is 258,160. Only a small portion of the population living within 600 miles of New Orleans discharges its sewage into the Mississippi River, as will be seen from the following table:

TABLE IX.

Showing the Population of Cities which Discharge Sewage into the Mississippi River above New Orleans and the Distances from the point of Discharge to New Orleans, by River.

CITY.	Population.	Distance from New Orleans.
Baton Rouge	11,269	131 miles.
Natchez	12,210	265 miles.
Alexandria	5,648	300 miles.
Vicksburg	14,834	554 miles.
	43,961	

It is to be remembered that the natural drainage in the Mississippi delta itself is away from the river, hence many cities do not discharge their sewage into the river, as would be the case in other parts of the country.

The estimated* discharge of the Mississippi river water is as follows:

Maximum......... 1,353,000 cubic feet per second.
Minimum........ 191,000 cubic feet per second.
Average.......... 685,000 (?) cubic feet per second.

If the above figures of population and discharge are considered, it will be seen that the dilution of the sewage of these four cities, which alone, in the light of our present knowledge, could be assumed

* Report of Mississippi River Commission.

to materially affect the sanitary quality of the river water in New Orleans, is as follows:

Maximum... 30,800 cubic feet per second per thousand people.
Minimum ... 4,350 cubic feet per second per thousand people.
Average...... 15,600 cubic feet per second per thousand people.

RAINFALL.

The following table shows the amount of rainfall in the Mississippi River Valley during the period of these investigations, compared with the normal rainfall. It will be seen that the precipitation during the period of these investigations has been much less than the normal, and although there seems to have been a great deal of rain at the head waters of the Mississippi and Ohio, there was a corresponding scarcity of rain in the water-sheds of these tributaries most productive of high amounts of suspended matter, the rainfall in the Missouri basin being especially low.

TABLE X.

Showing the Mean Yearly Rainfall in the Mississippi River Valley, also Rainfall for the Year ending September 1st, 1901.

BASIN.	Main Yearly Rainfall. Inches.	Rainfall Sept. 1st, 1900, to Sept. 1st, 1901.	Percentage which Rainfall is of the mean yearly Rainfall.
Ohio.			
Pittsburg	36.6	40.7	111.
Cincinnati	42.1	19.6	46.
Indianapolis	42.2	32.5	77.
Louisville	47.2	33.0	70.
Nashville	50.2	47.4	94.
		Average...	80.
Upper Mississippi.			
St. Louis	40.8	25 4	62.
Davenport	33.3	19.8	60.
La Crosse	30.7	40.2	131.
St. Paul	28.2	36.0	128.
		Average...	95.
Arkansas.			
Little Rock	54.2	41.2	76.
Red.			
Shreveport	48.2	35.9	74.
Central Valley.			
Cairo	42.6	32.1	75.
Vicksburg	52.7	51.8	98.
New Orleans	60.3	58.3	97.
		Average...	90.

STAGE OF THE RIVER.

During this investigation the stage of the Mississippi River was sometimes above and some times below the mean stage of the river for twenty-five years. On the average, however, the stage was lower. The following table, and the plate which accompanies this chapter, will show the comparison between the mean monthly stages of the Mississippi River for the year ending October 1st, 1901, and the mean monthly stages of the river for the past twenty-five years.

TABLE XI.

Showing the Mean Monthly Stages of the Mississippi River for the Year ending October 1st, 1901, compared with those for the mean of Twenty-five Years (Normal Year).

MONTH.	1900-1901.	Normal Year.
October	2.8	1.6
November	3.0	1.6
December	5.2	3.0
January	3.5	4.9
February	4.7	8.7
March	4.6	10.8
April	10.7	12.1
May	11.7	11.6
June	7.2	9.8
July	4.1	7.6
August	2.1	3.9
September	2.9	2.3
Mean	5.21	6.07

FLOODS.

The consideration of this topic is not so important, from a water purification standpoint here at New Orleans, as on some of the tributaries, for while the amount of suspended matter may be expected, roughly, to rise and fall with the stage of the river at all times on such tributaries as the Ouachita, the White (Ark.), and the Wabash, and while the writer believes that this general law may hold good for the Mississippi River at New Orleans, provided the data are extended over several years, it seems that there was only a remote relation between the stage of the river and the amount of suspended matter contained in the water during this investigation. This is due to differences in the rates of discharge of the main tributaries; the differences in the amounts of suspended matter contained in the water of the tributaries at different times; and the great number of permutations and combinations of these factors possible under such conditions. To illustrate, a flood may occur on the Red River while the river at New Orleans is at a low stage. The Red River is heavily charged with suspended matter during floods, but its discharge is less than that of any other main tributary. Therefore, the amount of suspended matter in the river at New Orleans might be greatly increased while the stage of

the river would be affected but slightly. Again, a flood from the comparatively clear Upper Mississippi River frequently follows after a flood from the turbid Ohio, thereby maintaining the stage of the river at New Orleans, while the suspended matter decreases in amount daily as the turbid Ohio water is displaced by that of the clearer Mississippi.

The following table from Bulletin E of the U. S. Weather Bureau, supplemented by data obtained from the report of the Mississippi River Commission, shows the significant data for the floods of the Mississippi River since 1872:

TABLE XII.

Floods and Highest Waters in the Mississippi River at New Orleans (Carrollton Gauge).

Year.	Highest Stage.	DATE.	River above Danger Line—13 Feet.		
			From—	To—	Number of Days.
1872	12.3	May 6.	....	....	0
1873	12.9	June 3, 4.	....	....	0
1874	16.0	April 15.	March 17.	May 18.	63
1875	11.3	May 3-5-14-16-18.	....	....	0
1876	12.7	May 11.	....	....	0
1877	11.1	June 4-8.	....	....	0
1878	11.3	March 21.	....	....	0
1879	10.8	February 20-22.	....	....	0
1880	14.2	April 23, 24.	March 22.	May 21.	61
1881	12.6	April 12.	....	....	0
1882	15.0	March 27.	February 11	May 12.	91
1883	15.4	April 7.	March 17.	June 16.	92
1885	13.6	January 22, 23.	January 22.	Feb'y 14.	24
1886	13.8	May 31.	April 27.	June 11.	46
1887	14.5	April 6-9.	March 9.	April 19.	42
1888	14.4	April 26	April 16.	May 11.	26
1889	11.6	March 13, 14.	....	....	0
1890	16.0	March 14-17-22.	February 3	May 30.	117
1891	16.0	March 16.	February 20	May 19.	89
1892	17.2	June 12, 13.	April 14.	July 25.	103
1893	13.2	March 17.	March 15.	March 23.	9
	17.4	June 22-24.	May 7.	July 14.	69
1894	13.4	April 5-7.	April 1.	April 12.	12
1895	10.1	April 8.	....	....	0
1896	13.7	April 24.	April 19.	April 27.	9
1897	19.0	May 7-14.	March 18.	June 13.	88
1898	13.8	February 15.	February 9.	Feb'y 19.	11
	15.9	April 25.	April 5.	June 10.	67
1899	16.1	April 21.	March 18.	May 19.	63
1900	12.5	March 28-30.	....	....	0
1901	12.7	May 15.	....	....	0

An inspection of the table will show the abnormally low stage of the river during the period of these investigations.

COMPARATIVE ABSENCE OF SUDDEN RISES.

Another noticeable fact in connection with the floods of the Mississippi River at New Orleans is the comparative absence of sudden rises and falls. Generally speaking, the mean annual oscillation of the Mississippi River is a long steady rise of about six months' duration, and a corresponding fall, the crest of the rise passing New Orleans about May 1st. The June rise, so apparent in the upper river, which is caused by a corresponding rise of the Missouri River, is apparent here only as a diminution in the rate of fall.

The Ohio is the most important of the tributaries affecting the stage of the river at New Orleans, and its rises are followed, on the average, by rises of the Upper Mississippi and Missouri, in close succession.

As a rule, the flood discharges of the Red and Arkansas Rivers have little or no effect upon the stage of the river at New Orleans. However, they often effect great changes in its physical and chemical character.

ENTRANCE OF GULF WATER DURING LOW STAGES OF THE RIVER.

When the stage of the Mississippi River becomes low, salt water enters the mouth of the river from the Gulf, and when the streamflow approaches very nearly its minimum, the taste of sea salt may become perceptible in the river water at New Orleans at rare intervals. Although the stage of the river was low during the past year, this was not noticed. It is said, however, that this occurrence was noted once in the last ten years, but at that time it was perceptible for a few days only.

In this connection, it is to be stated, that water taken from the surface of the river is less influenced by this factor than water taken from near the bottom. The explanation of this, of course, is to be found in differences in the specific gravity of the water. It may be said, in passing, that the presence of very small quantities of sea salt in the water supplies of some seaboard cities which are supplied from tidal streams is occasionally noted. A trained observer by tasting can detect as little as 200 parts of salt (sodium chloride) in a million parts of water. Prof. A. L. Metz, of this city, has announced that he found at least three times this amount in the Mississippi River water on one occasion during the last period of extreme low water. Some popular saline spring waters, however, found regularly on the local market, contain over 1000 parts of common salt per million. It may be stated

in positive terms that this feature of the local river water, based on past experience, would not be detrimental to the health of consumers.

As to the use of filtered river water for boiler purposes during very low river stages, it is likely that there might be a little extra "foaming" of the water in boilers, but there is no reason to expect serious increase in the amount of boiler scale. During such periods the amount of incrusting constituents increases somewhat, independently of the influence of Gulf water. Naturally, this causes a somewhat greater formation of boiler scale, which though chiefly due to calcium sulphate (gypsum), is, in some instances, at least, wrongly attributed to the presence of sea water. The maximum quantity of incrusting constituents during the past year did not exceed 30 parts per million—a very moderate figure for waters in the South and West.

EFFECT OF WIND STORMS UPON THE TURBIDITY OF THE MISSISSIPPI RIVER WATER.

Several times during the low water periods it was noticed that the turbidity of the water suddenly increased during wind and rain storms. This increase was caused by the erosion of the banks of the river, both by the waves and also by the rain water which fell upon and ran off from the battures. Upon investigation, it was found that this was a condition which prevailed only near the banks; as only very slight increases in turbidity were apparent at points from 50 to 100 feet distant from the shore line.

AMOUNT OF SUSPENDED MATTER NOT ALWAYS PROPORTIONAL TO THE STAGE OF THE RIVER.

The transporting power of a stream for suspended matter varies directly as the sixth power of its velocity, and because the velocity of the Mississippi River is a function of the height of its stage, one might expect that the water would be most turbid during highest stages, and *vice versa*. This theory is based upon the assumption that the Mississippi River always obtains as much eroded material as it can transport. Such is not the case; however, as the following citation from the records of this investigation will illustrate.

	Date.	Turbidity (Parts).	Stage of River. (Feet).
Highest turbidity	Dec. 6	1460	6.3
Highest gauge reading	May 15	400	12.7

These phenomena are explained by Humphrey & Abbott* as being possible because the amount of sediment contained in the river is far less than the transporting power of the stream would allow, provided the necessary material to be transported was at hand. Assuming this

*loc. cit.

theory to be correct—and the results of this investigation indicate that it is—it follows that a flood in the Red or Arkansas Basins, when the Missouri and Ohio Rivers are both at their low stages, may materially increase the turbidity of the river at New Orleans. Likewise, the turbidity is increased when large amounts of material are being thrown into the river by the surface caving or sloughing off of the banks of the stream during falling stages. The material thus obtained is naturally composed of differently sized particles, varying from coarse to extremely fine; the former settles out very soon, while the latter persists to the mouth of the river.

SYNOPSIS OF THE LEADING FEATURES OF THE MISSISSIPPI RIVER.

Although the average stage of the Mississippi River during these investigations was comparatively low, and, as a consequence, abnormal conditions prevailed, it is thought best to describe the leading characteristics of the water as they occurred, and also to estimate the significant data for a normal year as accurately as the information at hand will allow.

Summary of the Amounts of the Several Constituents Found in the River Water for the Period Between December 10th, 1900, and August 17th, 1901.

CONSTITUENTS.	PARTS PER MILLION.		
	Maximum.	Minimum.	Average.
Silica Turbidity	1460.	90.	405.
Total Suspended Matter	1250.	75.	440.
Total Dissolved Residue	250.	80.	145.
Nitrogen as Suspended Albuminoid Ammonia	0.598	0.015	0.188
Nitrogen as Total Albuminoid Ammonia	0.677	0.054	0.251
Nitrogen as Free Ammonia	0.036	0.000	0.012
Nitrogen as Nitrites	0.023	0.000	0.008
Nitrogen as Nitrates	0.56	0.02	0.14
Chlorine	20.9	6.0	9.2
Incrusting Constituents	24.	5.	14.
Alkalinity	115.	57.	79.
Dissolved Oxygen	11.5	5.3	9.0
Free Carbon Dioxide	75.	0.	34.
Bacteria per Cubic Centimeter	6500.	60.	[illegible]
Temperature—Degrees C	31.1	17.0	17.6

ANALYTICAL DESCRIPTION OF T MISSIS

The above table gives the results of the investigation. It i the amounts of those constituen

water purification standpoint and to give a more detailed description of other constituents which affect the general character of the river water.

PLAN OF ANALYTICAL WORK.

Complete physical, chemical and biological examinations of the water were made throughout the whole investigation, as required.

SAMPLES.

From October 1st until December 10th, 1900, daily samples of the river water were taken, but only for the determination of turbidity, chlorine and alkalinity. Beginning December 10th, complete physical, chemical and bacterial analyses were made of daily average samples of river water, but as the work progressed, the daily determination of the less important constituents was discontinued. When the plant was put into operation, frequent samples of the basin and filter effluents were taken, some for the determination of turbidity, some for the determination of turbidity and bacteria, and others for complete analysis.

A few determinations of the number of higher microscopical plants and animals contained in the river and settled waters were made from time to time. Frequent bacterial examinations were made of the various samples to determine, first, the presence or absence of Bacillus coli communis and Bacillus enteritidis sporogenes, two species associated with sewage pollution, and, second, to identify several species of bacteria, including some species not hitherto described, which constituted the flora of the river water.

METHODS OF ANALYSIS.

Physical.

Color.—The Hazen platinum-cobalt standard was used. In order to have the results in harmony with the results of other determinations, it has been decided to express them as parts per million instead of parts per 10,000 as has been [illegible]tice.

Silica Turbi[illegible] diap[illegible] (described elsewhere*) was used in order [illegible] of the various samples by optical means [illegible] vanishing depth of a brightly illum[illegible] d at the bottom of [illegible] The instrument [illegible] of standard sus- [illegible] When tables of

[illegible]ber, 1899.

equivalents had been prepared, the results of turbidity determinations by this optical method were expressed as the number of parts of silica which produced the same turbidity. These results are classified under "silica turbidity", to distinguish them from the results of other turbidity determinations by other methods.

It was impracticable to determine the turbidity, by the diaphanometer, of waters which had less than 40 parts per million of silica turbidity on account of the length of the tube of the instrument. Therefore, when the turbidity of the water was equivalent to that produced by less than 50 parts of silica per million, the samples were compared directly with the standard suspensions of silica, both contained in white glass bottles. On the other hand, accurate comparisons in bottles could not be made as satisfactorily as with a diaphanometer, when the samples had a silica turbidity of over 60 parts per million. The results of this silica turbidity determination were corrected for significant figures, as follows:

Turbidity Parts of Silica	Recorded to
1 to 35	Nearest unit.
36 to 100	" 5
101 to 300	" 10
301 to 1000	" 25
1001 to 3000	" 50

During the investigation, comparisons of these methods with the wire, or Hazen, method were frequently made. This wire method expresses the turbidity as the reciprocal of the vanishing depth, in inches, of a bright platinum or aluminum wire, one millimeter in diameter, fastened at the end of a graduated rod and at right angles to its length. This wire method is the one in most general use and the one most applicable for field work during daylight. In the hands of the ordinary observer it does not seem to give precise results with waters which have a silica turbidity of over 400 parts per million. The samples which have a high turbidity must be first diluted before the estimation is made. The diaphanometer can be used during day or night.

The following table suffices to compare the results of observation by the different methods within their limits of accuracy. Samples which were too turbid to be read accurately by any of the methods were first diluted with known amounts of distilled water. The figures given are the means of a large number of observations, extending through several months, and are indicative of the results which could be expected of the average trained analyst:

TABLE XIII.

Table Showing the Relation between the Various Methods of Turbidity Determination.

By Direct Comparison with Silica Standards.	By Diaphanometer Expressed as Parts of Silica per Million.	Wire Reciprocal of Vanishing Depth in inches.
5	.....	0.018
10	......	0.037
15	......	0.049
20	......	0.070
25	......	0.078
30	......	0.090
40	40	0.12
50	50	0.15
60	60	0.18
......	70	0.21
......	80	0.24
......	90	0.27
......	100	0.30
......	120	0.35
......	140	0.40
.....	160	0.44
......	180	0.48
......	200	0.52
......	220	0.55
......	240	0.58
......	260	0.62
......	280	0.66
......	300	0.69
......	320	0.72
......	340	0.76
......	360	0.79
......	380	0.82
......	400	0.86
......	450	0.94
......	500	1.02

The above are average determinations on samples from all sources.

Single determinations by the diaphanometer varied from time to time with different intensities of light, different observers, and different suspensions of silica. The total variation reached 15 per cent, at times. The personal error of reading was as much as 7 per cent. The two suspensions of silica used were practically identical, being prepared from the same diatomaceous earth.

Turbidity Co-efficient—All optical methods for the determination of turbidity are naturally compared with the gravimetric determination of the suspended matter which produces the turbidity. Equal weights of suspended matter do not necessarily produce the same turbidity. For example, waters which contain suspended silt or sand exhibit less turbidity per unit of suspended matter by weight than do waters containing finely divided clay. Therefore, the ratio between

silica turbidity, determined optically, and suspended matter, determined gravimetrically, is most important, as it is an index of the character of the suspended matter producing the turbidity. To express this relation most conveniently, the term "turbidity co-efficient" has been adopted.

$$\text{Turbidity Co-efficient equals} \ldots\ldots \frac{\text{Suspended Matter.}}{\text{Silica Turbidity.}}$$

Naturally, this co-efficient varies with different waters, generally increasing with the size of the particles composing the suspended matter. Thus, the samples of unsettled river water have the highest turbidity co-efficient, while samples from the effluents of the three-day subsiding basins have the lowest, as the following table will show:

TABLE XIV.

Table of Average Turbidity Co-efficients.

Water.	Turbidity Co-efficient.
Mississippi River water	1.08
Mississippi River water, after 6 hours' subsidence	0.90
Mississippi River water, after 12 hours' subsidence	0.87
Mississippi River water, after 18 hours' subsidence	0.86
Mississippi River water, after 24 hours' subsidence	0.85
Mississippi River water, after 48 hours' subsidence	0.80
Mississippi River water, after 72 hours' subsidence	0.76
Mississippi River water, after 24 hours' subsidence and coagulation	0.60

This table is very easy to understand, since the coarser particles of low turbidity-producing power and somewhat higher specific gravity gradually separate out according to their hydraulic values, the finer particles of high turbidity-producing power and somewhat lower specific gravity remaining longest in suspension.

CHEMICAL.

In general, the methods advised by the American Public Health Association Committee, which was appointed to recommend uniform methods of water analysis, have been followed.

DETERMINATION OF SUSPENDED MATTER—GRAVIMETRIC.

The suspended matter was determined by estimating the residue on evaporation of the water, both before and after being passed through a Berkfeldt filter tube, the difference between these results being the suspended matter. Pasteur filter tubes were tried, but were found to introduce errors into the determination, while the error arising from the use of the Berkfeldt filter tube, which was used throughout most of the investigation, was negligible. All residues were dried at 105 degrees C. for at least one hour before cooling and weighing. Much difficulty was experienced during the rainy summer months in

weighing the dishes containing the residues; in fact, for two weeks at one time during a period of daily showers, the humidity was so great that the correct weighing of the residues was impossible. All results of this determination are recorded to the nearest five parts per million, in order to escape fictitious accuracy.

BACTERIAL.

The bacterial work was carried out in brief, as follows:

Quantitative.—One cubic centimeter of the water, diluted if necessary, was mixed with five cubic centimeters of 10 per cent nutrient gelatine of a 2 per cent acid reaction, contained in a petri dish. The gelatine was then hardened in the ice box and incubated for two days, at a temperature of from 19 to 20 degrees Centigrade. The colonies were then counted in the usual way. Media containing 12 per cent of gelatine was used during the summer months.

Owing to the large number of liquefying colonies present, the cultures could not be incubated much longer than two days without becoming completely liquefied; in fact, on the average, about 15 per cent of the surfaces of the plates were liquefied at the time of counting. As high a temperature (19 degrees to 20 degrees) was maintained as would allow the plates to develop visible colonies and at the same time avoid liquefaction.

Some difficulty was experienced with spreading colonies, which were caused by the condensation of moisture on the surface of the gelatine during periods of very humid atmosphere. The bacterial counts were corrected for significant figures, as follows:

Number of Colonies.	Recorded to
1 to 50	Nearest unit
51 to 100	" 5
101 to 250	" 10
251 to 500	" 25
501 to 1000	" 50
1001 to 5000	" 100
5001 to 10000	" 500

QUALITATIVE—METHOD FOR BACILLUS ENTERITIDIS SPOROGENES (KLEIN*).

From 1 to 25 cubic centimeters of the sample of water were mixed with from 10 to 100 cubic centimeters of sterile neutral milk. The whole was then put in an atmosphere of hydrogen and incubated for two days at 37 degrees C. Cultures which then produced a characteristic coagulation of the milk and an odor of butyric acid were inoculated into Guinea-pigs—one cubic centimeter of the clear whey being allowed to each 200 grams of the animal weight. If the Guinea-pig died with the formation of characteristic lesions, the identity of the bacillus was considered established.

* For details of method, see Klein's original article in the report of the Medical Officer of the British Local Government Board for the years 1895 to 1898.

METHOD FOR BACILLUS COLI COMMUNIS.

The method used varied considerably during the course of the work. At the beginning, when the bacterium was occasionally isolated, from 1 to 25 cubic centimeters of the sample to be tested were sown into dextrose-broth and the cultures showing positive results were plated out on lactose-litmus-agar plates. Characteristic red colonies were then selected for seeding the various conventional media. Later on, however, it was necessary to concentrate a large sample of water—300 cubic centimeters—in a centrifugal machine. The concentrate was then sown into phenol-dextrose-broth contained in fermentation tubes, which was incubated at blood temperature for forty-eight hours. Cultures which then showed the possible presence of the looked-for bacteria were sown on lactose-litmus-agar plates as described above.

The results of most of the above works were negative.

PHYSICAL CHARACTER OF THE MISSISSIPPI RIVER WATER.

This part of the analytical description supplements what has been written above. The following physical characteristics demand consideration:

Color.—The Mississippi River water, independent of the suspended matter contained therein, has almost no color. This color is so small in amount that only a trained observer would detect it. This fact is especially remarkable because the drainage of many of the water-sheds in the Central Valley, and at times, the water of the Upper Mississippi, are quite highly charged with dissolved color which, however, becomes absorbed by the clay particles, so that when the sediment is removed, the color is removed with it.

Odor.—The Mississippi River water has a very faint vegetable—earthy odor. This odor would not be ordinarily detected by the average consumer, but can be detected in the laboratory by an experienced observer.

Taste.—The Mississippi River water, in its natural condition, has a very slight taste, which may be designated as clayey or earthy, and which is due to the suspended matter entirely, because, when the suspended matter is removed, this taste disappears. The taste of the filtered water is all that can be desired, its pleasantness being doubtless enhanced by the amount of carbon dioxid (carbonic acid gas), which is dissolved in the water.

Suspended Matter.—Previous to and during this investigation, the methods for the optical determination of suspended matter (silica turbidity), have been so improved that they form the most useful basis for the comparison of the amounts of suspended matter contained in the local water at different times.

The average amount of suspended matter, determined gravimetrically, contained in the Mississippi River water during this investigation was 441 parts per million, and the average silica turbidity of the water, determined optically, was 405 parts per million. The relation between these is best expressed by the "turbidity co-efficients" (suspended matter divided by the silica turbidity, see page 27) which averages 1.08 for the period of these investigations.

The record of the daily average silica turbidity is included in the table showing the composition of the Mississippi River water, following page 38.

From what foregoes it is easily seen that during the period of these investigations the amount of rainfall and the mean stage of the river were somewhat below the normal. The amounts of suspended matter were also below the normal. The results obtained by the Mississippi River Commission demonstrate the truth of this statement, as is shown in the following table. These results extend over fifteen years:

TABLE XV.

Suspended Matter Contained in the Mississippi River Water at Carrollton, La. (New Orleans.) Parts per Million.

Year.	Average Suspended Matter.	Average Suspended Matter—Corrected.
1879.	456	434
1880.	803	769
1881.	825	785
1882.	642	610
1883.	817	779
1884.	589	561
1885.	877	835
1886.	543	517
1887.	641	611
1888.	1098	1044
1889.	521	496
1890.	574	547
1891.	581	552
1892	732	698
1893.	621	592
Averages....................	688	649

Reference: Report of the Chief of Engineers U. S. Army, 1894, p. 1345.

Author: Report of Major James B. Quinn.

MEAN MONTHLY AVERAGE AMOUNTS OF SUSPENDED MATTER, BASED ON FOREGOING DATA.

The average amount of suspended matter contained in the river water during each month of a normal year is as follows:

TABLE XVI.

Showing the Mean Average Amounts of Suspended Matter Contained in the Mississippi River Water, Expressed as Parts per Million.

Month.	Suspended Matter.
January	385
February	640
March	1150
April	1425
May	1350
June	920
July	600
August	410
September	290
October	185
November	160
December	260
Average	650

The method used by the Mississippi River Commission to obtain the above values provides for the drying of the suspended matter first collected upon a tared filter, at room temperature, while the customary laboratory methods provide for the drying of the residue upon evaporation, in platinum dishes, at a temperature of 105 degrees C. It was learned that when the same samples of water were tested by both methods in this laboratory, that the methods used by the Mississippi River Commission gave results which averaged 5 per cent too high. This excess was due to the presence of unexpelled moisture in the suspended matter as weighed by the analysts of the Mississippi River Commission.

Applying the above correction to the results in the table, we may then assume that the mean amount of suspended matter in the Mississippi River water at New Orleans is about 650 parts per million. If the turbidity co-efficient (1.08) determined during this investigation, is assumed to be correct for the normal condition of the river, then the mean silica turbidity of the river water is about 600 parts per million. The average silica turbidity for the year ending September 30th, 1901, was 370 parts per million, therefore, it may be assumed that the river water contained only about two-thirds of the silica turbidity during this investigation which it would have contained during a normal year.

CORRECTNESS OF TURBIDITY CO-EFFICIENT.

Perhaps one assumption in this estimate may be questioned, namely, the value of the turbidity co-efficient (1.08) for average conditions. This was determined during the abnormal conditions of these investigations when the average amount of suspended matter was nearly as low as that of the lowest year of the fifteen years recorded by the Mississippi River Commission in the above table. The question

; based upon the general hypothesis that the coarseness of the sus-ended matter increases as the velocity of the stream, and, therefore, ne turbidity co-efficient would correspondingly increase.

The fact that the Missouri river was abnormally low this season nd that much of the suspended matter contained therein was probably ery coarse, is also a cause for doubting this assumption. These bjections would, of course, be well-grounded if the Misssissippi River vere completely charged with suspended matter at all times. Such, owever, is not the case, and the results of this investigation confirm he opinion that the turbidity co-efficient varied independently of the tage of the river, as the following table will show:

TABLE XVII.

howing the Average Monthly Gauge Readings and the Average Turbidity Co-efficients of the Mississippi River Water at New Orleans.

Average Gauge Readings, 1900-1901.		Turbidity Co-efficient.	Average Suspended Matter.
Month.	Feet.		
)ecember	5.2	0.95	449
anuary	3.5	1.18	223
'ebruary	4.7	1.29	294
Iarch	4.6	1.13	425
Npril	10.7	1.14	713
Iay	11.7	1.06	436
une	7.2	1.03	469
uly	4.1	0.88	527

At certain periods of low velocity, however, the Mississippi River, elow the mouth of the Red River, acts as a vast subsiding basin, nd the water has a low turbidity co-efficient, while at certain, not ll, periods of flood reverse conditions may be met with. For any hort period of days, the turbidity co-efficient of the Mississippi River vater is not exactly constant within the limits of accuracy of the etermination.

The averages of the "suspended matter" and "silica turbidity" esults on twenty-two samples of water, which contained between 600 nd 700 parts and averaged 648 parts of suspended matter per million, re 652 and 607, respectively; hence the turbidity co-efficient for this ondition is 1.07, which is within 1 per cent of the turbidity co-effi-ient—1.08, the average result of over seven months' observation. Therefore, it seems quite safe to assume that, on the average, the 'suspended matter" in the Mississippi River water is equal to 1.08 imes the silica turbidity as determined optically.

For convenient reference, the significant physical data for the Mississippi River water at New Orleans are grouped as follows:

TABLE XVIII.

Summary of the Physical Data.

Average Suspended Matter, 1900-1901.........	441 parts per million
Average Silica Turbidity, 1900-1901.............	406 parts per million
Average Turbidity Co-efficient, 1900-1901	1.08.
Average Recorded Suspended Matter, fifteen years..	§688 parts per million
Average Suspended Matter Corrected for Analytical Errors......................................	650 parts.
Average Turbidity Co-efficient for twenty-two samples of water having between 600 and 700, and averaging 648 parts of suspended matter per million................................	1.07.
Estimated Mean Silica Turbidity.................	600 parts.
Maximum Suspended Matter, 1900-1901........	1250 parts.
Maximum Suspended Matter, fifteen years.....	§2500 parts.
Estimated Mean Maximum Silica Turbidity...	1500 parts.
Estimated Mean Minimum Silica Turbidity...	125 parts.

§ Report of Mississippi River Commission.

DAILY NORMAL AMOUNTS OF SILICA TURBIDITY.

It is desirable to estimate the amount of silica turbidity which the water contains for each day of a normal year. In addition to the above data, the records of the stages of the river must be taken into account. The plate which accompanies this chapter depicts the following data:

(*a*) Mean hydrograph of the Mississippi River for twenty-five years.

(*b*) Hydrograph of the Mississippi river for the year ending September 30, 1901.

(*c*) Curve of the average daily silica turbidity of the Mississippi River for the year ending September 30, 1901.

(*d*) Curve of normal (mean) silica turbidity.

(*e*) Curve of average silica turbidity for 1900–1901.

It is assumed that the normal curve of silica turbidity would vary on the average with the normal hydrograph, and that the maximum and minimum normal turbidities would be approximately coincident with the mean maximum and the mean minimum stages of the river.

The following table is based upon the foregoing evidence, and shows the estimated silica turbidity for each day of the normal year:

TABLE XIX.

Showing the Estimated Silica Turbidity of the Mississippi Water for Each Day of the Normal Year.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	230	425	780	1350	1500	1125	620	400	280	240	125	140
2	240	435	790	1350	1500	1125	610	400	280	240	125	140
3	245	440	810	1350	1500	1100	600	390	270	230	125	150
4	245	455	830	1375	1500	1075	580	390	270	220	125	150
5	250	465	850	1375	1475	1050	570	380	270	220	125	150
6	255	470	860	1400	1475	1025	560	380	270	220	125	150
7	260	480	880	1400	1475	1025	550	370	270	210	125	160
8	265	490	900	1400	1475	1000	540	370	260	210	125	160
9	270	500	920	1425	1475	980	530	360	260	200	125	160
10	280	510	950	1425	1450	960	520	360	260	200	125	160
11	285	520	980	1450	1450	940	520	350	260	190	130	170
12	290	535	990	1450	1450	920	510	350	260	190	130	170
13	295	550	1000	1450	1450	910	510	340	260	180	130	170
14	300	560	1025	1450	1425	890	500	340	260	180	130	170
15	310	570	1050	1450	1425	880	490	340	250	170	130	170
16	315	580	1075	1450	1400	850	480	330	250	170	130	170
17	320	600	1100	1475	1400	830	480	330	250	160	130	180
18	325	620	1100	1475	1375	820	470	330	250	160	130	180
19	330	630	1125	1475	1350	800	470	320	250	150	130	180
20	340	640	1150	1475	1325	780	460	320	250	150	130	180
21	345	650	1175	1475	1325	770	450	320	250	150	140	190
22	350	660	1175	1475	1300	750	450	310	250	140	140	190
23	360	680	1200	1475	1300	730	440	310	250	140	140	190
24	365	700	1225	1475	1275	720	440	310	240	140	140	200
25	370	710	1250	1475	1275	700	430	300	240	140	140	200
26	380	730	1275	1500	1250	690	430	300	240	130	140	210
27	385	740	1275	1500	1225	670	420	300	240	130	140	210
28	390	760	1300	1500	1200	660	420	290	240	130	140	210
29	400	770	1300	1500	1200	640	420	290	240	125	140	220
30	410	......	1325	1500	1175	630	410	290	240	125	140	220
31	415	.....	1325	......	1150	......	410	280	......	125	......	220

ABSORPTION OF COAGULANT BY SUSPENDED MATTER.

When sulphate of alumina is added to the river water for the purpose of coagulation, a certain amount is absorbed by the suspended matter contained in the water, and does not react with the dissolved carbonates to form alumina hydrate. Theoretically, each grain of sulphate of aluminum used during this investigation, when added to a gallon of water, would react with 8.2 parts per million of dissolved carbonates, *i. e.*, the alkalinity of the water would be reduced by 8.2 parts per million; the difference between the actual and the theoretical reduction of alkalinity is a measure of the amount of sulphate of alumina absorbed directly by the suspended matter.

The following table shows the results of several experiments made in this laboratory to determine the extent of this reduction with the various classes of local river water. These results vary greatly according to the composition of the river water at the time the experiments were made. It was learned that the greatest absorption occurred when the local water most resembled the Red River water in character:

TABLE XX.

Showing Reduction of Alkalinity in, and Absorption of Coagulant by, Mississippi River Water.

Date 1901	Silica Turbidity	Alkalinity of River Water	Reduction of Alkalinity, in Parts per Million, per Grain Coagulant per Gallon Water.								
			1.0 Grains	1.5 Grains	2.0 Grains	3.0 Grains	4.0 Grains	5.0 Grains	6.0 Grains	Average	Theoretical Reduction
April 11	660	75.0	......	7.0	7.8	7.1	7.3	7.4	6.8	7.2	8.2
" 23	520	71.7	......	7.0	7.9	7.8	6.9	6.9	7.3	7.1	8.2
" 27	660	72.8	......	6.8	7.1	7.5	7.7	7.1	7.0	7.1	8.2
May 9	510	70.6	......	......	8.5	7.6	7.8	7.3	7.7	7.8	8.2
June 3	440	103.5	0.5	......	2.8	4.3	5.5	5.4	5.2	4.0	8.2
" 6	540	102.7	4.0	......	4.7	5.1	5.7	6.0	6.7	5.4	8.2
" 12	450	81.5	......	......	8.3	7.7	7.3	7.1	7.2	7.5	8.2
" 20	450	77.0	......	......	7.6	7.3	6.5	6.8	6.8	7.0	8.2
" 27	325	80.9	......	......	6.2	6.8	7.8	7.0	6.2	6.8	8.2
July 9	660	93.5	4.4	......	6.0	7.8	7.4	6.0	6.0	6.3	8.2
" 12	700	86.2	2.8	.....	3.6	5.1	5.3	5.6	5.3	4.5	8.2
" 18	725	85.7	6.0	......	5.9	5.6	5.7	6.1	6.3	5.9	8.2

CHEMICAL CHARACTER OF THE RIVER WATER.

The following set of tables contains the results of regular sanitary and technical chemical analyses of the river water, including, also, as a matter of convenience for reference, the average numbers of bacteria and the records of color, turbidity and temperature.

EXPLANATION OF THE TABLES.

Certain points in these tables need a brief explanation, as follows:

Form of Expression.—All results are expressed as parts per million, meaning milligrams per liter. A table for the conversion of the different forms of expression, in common use, is given in Chapter VIII.

Oxygen Consumed.—This determination is considered to be a measure of the amount of carbonaceous organic matter contained in the water. It is not a measure of the nitrogen content.

Nitrogen as Albuminoid Ammonia.—This determination is a measure of the amount of nitrogeneous (albuminous) organic matter. The results of this determination are recorded as total, suspended and dissolved albuminoid ammonia. It may be noted, in passing, that the organic matter is mostly absorbed by the suspended matter and forms but a small portion of the dissolved matter contained in the water.

Nitrogen as Free Ammonia.—When the water is distilled without the addition of chemicals, a certain amount of ammonia is carried over with the distillate. This is called free ammonia and is a measure of the amount of nitrogen in the form of ammonia which has been set free by the decomposition of nitrogenous organic matter. In other words, it is the first step in the decomposition of nitrogenous organic matter through the action of bacteria in the presence of oxygen.

Nitrogen as Nitrites.—This process of decomposition is called nitrification, and this determination shows the amount of nitrogen which has reached or is passing through the second stage of the process.

Nitrogen as Nitrates.—This determination indicates the amount of completely oxidized mineral nitrogen which has passed through the cycle of changes. Water containing nitrates is admirably suited to the growth of microscopic plants (algæ). They, in turn, furnish food for animals (infusoria and fish), which, in turn, pass through the cycle of changes from albuminoid ammonia to nitrates.

Chlorine.—Chlorine is present in the water largely as common salt. In some localities it is customary to record this as a measure of sewage contamination. Here at New Orleans, however, one must take into account the number of mineral deposits which affect the character of the river water, especially those in the southwestern river basins.

Incrusting Constituents.—This determination includes the chlorides and sulphates of calcium and magnesium, substances which are important from a technical standpoint, chiefly because they form incrustations in steam boilers.

Alkalinity.—This determination is an index of the amount of magnesium and calcium carbonates contained in the water. It is also a measure of the power which the water has to decompose the coagulating chemical used in connection with certain systems of water purification. Some analysts record the "total hardness" or the soap destroying power of a water. This value is approximately equal to the sum of the alkalinity and the incrusting constituents.

Residue on Evaporation.—This determination measures the amount of solid matter contained in the water after evaporation. It is made on the sample of water both before and after passing through a Berkfeldt filter tube. The method is also discussed in connection with the determination of silica turbidity on page 25.

The suspended residue is the constituent of the water which must be entirely removed by any successful system of purification, therefore, the record of its amount and character is the most important feature of the tables.

Iron.—This determination is of little importance except as it evidences the character of the suspended matter, because practically all the iron contained in the water is in suspension.

Carbon Dioxid.—There is considerable carbon dioxid (carbonic acid), contained in the river, both free and also combined with calcium and magnesium. The degree of alkalinity of the water is more or less dependent upon the amount of carbon dioxid contained therein, since calcium and magnesium are much more soluble in water containing it than in water containing none. The corroding power of water is largely dependent upon the amount of carbon dioxid contained in it.

Dissolved Oxygen.—This determination is the measure of the amount of atmospheric oxygen absorbed by the water, and is most important in connection with the consideration of the corroding power

of a water, especially in connection with the study of the action of water upon metals.

LIST OF TABLES.

TABLE XXI. This table gives the results of the turbidity, alkalinity and chlorine determinations which were made between October 1st and December 15th, the latter being the date when complete analyses were begun.

TABLE XXII. This table gives the results of regular sanitary and technical chemical analyses, including the average numbers of bacteria.

TABLE XXIII. This table contains the results of partial mineral analyses of the Mississippi River water.

Beyond an increase in the amount of sulphate, due to the influences of the Southwestern tributaries, the amounts of dissolved mineral constituents varied but little during the investigation.

TABLE XXI.

Showing Turbidity, Alkalinity and Chlorine Contained in the Mississippi River Water, from October 1, 1900, to December 15, 1900.

DATE.	Silica Turbidity.	Alkalinity.	Chlorine.	DATE.	Silica Turbidity.	Alkalinity.	Chlorine.
October 1	90	116	14.3	November 9	260	98	....
.. 2	90	114	14.2	.. 10	240	98	....
.. 3	75	113	13.0	.. 12	250	99	....
.. 4	80	120	12.6	.. 13	270	103	....
.. 5	80	121	12.0	.. 14	270	98	....
.. 6	100	123	12.4	.. 15	280	95	....
.. 8	140	125	10.1	.. 16	300	92	....
.. 9	140	126	10.5	.. 17	320	86	....
.. 10	140	133	10.1	.. 19	600	83	....
.. 11	140	133	10.3	.. 20	500	85	....
.. 12	140	135	10.6	.. 21	550	84	....
.. 13	140	136	10.9	.. 22	500	86	....
.. 15	150	132	11.3	.. 23	625	87	....
.. 16	220	130	11.4	.. 24	500	92	....
.. 17	220	124	11.2	.. 26	425	88	....
.. 18	200	125	11.3	.. 27	350	93	....
.. 19	250	122	44.1	.. 28	325	89	....
.. 20	325	116	36.7	.. 29	325	94	....
.. 22	350	112	19 9	.. 30	500	96	....
.. 23	290	105	16.6	December 1	850	100	....
.. 24	260	104	13.5	.. 2	750	99	....
.. 25	230	101	11.6	.. 3	625	97	.....
.. 26	210	99	12.0	.. 4	925	94	....
.. 27	220	120	13.2	.. 5	1200	86	....
.. 29	230	101	14.6	.. 6	1450	82	....
.. 30	260	97	13.9	.. 7	1350	84	....
.. 31	280	96	12.8	.. 8	1250	70	.. ....
November 1	240	102	11.9	.. 9	1225	70	....
.. 2	230	99	11.0	.. 10	1200	71	.. ..
.. 3	280	97	11.1	.. 11	1200	59	....
.. 5	300	99	....	.. 12	1300	68	....
.. 6	280	89	....	.. 13	1300	69	....
.. 7	270	99	....	.. 14	1250	71	....
.. 8	270	97	....	.. 15	1250	65	....

TABLE NO. XXII.—*Composition of the Mississippi River Water.*

DATE. 1900	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	NITROGEN AS — Ammonia. — Albuminoid. — Dissolved.	Albuminoid. — Suspended.	Albuminoid. — Total.	Ammonia. — Free.	Nitrites.	Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	RESIDUES ON EVAPORATION. — Dissolved.	Suspended.	Total.	Iron.	CARBON DIOXIDE. — Free and Half-bound.	Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Dec. 10	......	1200	10	......	0.164	0.436	0.600	0.003	......	......	6.6	22	71	140	1,040	1,180	......	......	...	......	2 008
" 11	......	·200	15	......	0.134	0.416	0.550	0.015	......	......	11.3	22	59	140	1,040	1,180	......	......	...	......	2,200
" 12	......	1300	15	15.1	0.122	0.378	0.500	0.004	0.021	0.13	9.8	20	68	155	950	1,110	24.5	......	...	......	2,400
" 13	......	1300	25	16.2	0.119	0.371	0.490	0.036	0.022	0.12	7.0	16	69	160	980	1,140	24.5	......	...	......	2,500
" 14	......	1300	18	15.7	0.116	0.349	0.465	0.033	0.023	0.11	6.3	23	71	160	950	1,110	25.5	......	...	......	1,300
" 15	......	1300	16	12.2	0.083	0.332	0.415	0.033	0.006	0.32	47.3	...	65	185	895	1,080	23.0	......	...	......	1,700
" 17	......	875	15	7.2	0.136	0.179	0.315	0.021	0.016	0.26	......	23	71	120	390	510	17.5	......	...	......	1,600
" 18	......	950	15	9.0	0.126	0.254	0.380	0.025	0.023	0.25	8.3	19	61	125	610	735	24.0	......	...	......	1,500
" 19	......	550	17	8.8	0.092	0.198	0.290	0.013	0.023	0.56	7.5	20	62	80	500	580	19.0	......	...	......	1,100
" 20	......	400	15	8.0	0.089	0.226	0.315	0.020	0.018	0.26	7.3	18	57	120	515	635	17.5	......	...	......	800
" 21	......	325	17	6.8	0.069	0.221	0.290	0.007	0.017	0.18	8.5	19	61	90	390	480	15.0	......	...	......	3,100
" 22	......	325	9	5.6	0.098	0.157	0.255	0.008	0.010	0.28	8.8	18	60	125	375	500	19.5	......	...	......	2 400
" 24	......	350	10	4.8	0.080	0.167	0.247	0.008	0.017	0.25	8.0	13	57	135	400	535	14.5	......	...	......	1,200
" 26	......	270	11	6.3	0.082	0.141	0.223	0.011	0.011	0.18	7.2	...	70	165	300	465	15.0	......	...	......	1,800
" 27	......	290	9	5.9	0.085	0.122	0.207	0.024	0.004	0.23	8.0	...	72	175	280	455	17.5	......	...	......	5,000
" 28	......	270	8	4.6	0.101	0.093	0.194	0.019	0.008	0.22	7.5	21	73	140	160	300	14.5	......	...	......	2,000
" 29	......	240	10	5.2	0.102	0.074	0.176	0.020	0.007	0.29	7.5	17	75	160	200	360	15.0	......	...	......	3,000
" 30	......	230	10	5.0	0.086	0.120	0.206	0.012	0.006	0.26	8.5	22	72	160	230	390	19.0	......	...	......	1,900
" 31	......	230	11	4.7	0.095	0.104	0.199	0.015	0.006	0.18	9.0	18	71	160	225	385	18.0	......	...	......	900
Jan. 1—1901	......	220	10	4.7	0.098	0.101	0.199	0.016	0.006	0.18	8.8	16	72	150	210	360	14.5	......	...	......	500
" 2	9.3	210	9	4.6	0.062	0.132	0.194	0.013	0.012	0.16	8.5	10	71	200	185	385	14.0	......	...	......	1,800
" 3	......	180	10	4.2	0.060	0.084	0.144	0.004	0.013	0.16	9.5	14	75	170	190	360	14.0	......	...	......	6,500
" 4	......	200	10	4.4	0.064	0.068	0.132	0.011	0.012	0.14	9.3	6	74	165	130	295	13.0	......	...	......	2,100
" 5	......	175	11	4.2	0.081	0.050	0.131	0.008	0.004	0.17	8.9	5	75	135	200	335	14.0	......	...	......	600
" 6	......	180	9	4.1	0.079	0.052	0.131	0.016	0.006	0.18	9.5	7	74	140	200	340	10.0	......	...	......	600
" 7	8.9	180	10	4.0	0.064	0.056	0.120	0.020	0.009	0.19	10.3	21	76	145	180	325	12.5	......	...	......	......
" 8	8.9	170	8	3.9	0.066	0.035	0.101	0.021	0.008	0.13	10.5	10	76	155	160	315	14.0	......	...	......	......
" 9	9.0	160	8	3.9	0.069	0.031	0.100	0.007	0.004	0.24	10.0	11	80	155	160	315	10.0	......	...	......	100
" 10	9.3	170	10	3.9	0.072	0.060	0.132	0.014	0.012	0.13	10.1	18	80	155	175	330	12.5	......	...	......	1,300
" 11	9.2	150	10	4.7	0.056	0.078	0.134	0.025	0.016	0.08	10.6	15	66	155	170	325	10.0	......	...	......	850

Table No. XXII.—Continued.—*Composition of the Mississippi River Water.*

Date. 1901	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as — Ammonia — Albuminoid — Dissolved.	Nitrogen as — Ammonia — Albuminoid — Suspended.	Nitrogen as — Ammonia — Albuminoid — Total.	Nitrogen as — Ammonia — Free.	Nitrogen as — Nitrites.	Nitrogen as — Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation — Dissolved.	Residues on Evaporation — Suspended.	Residues on Evaporation — Total.	Iron.	Carbon Dioxide — Free and Half-bound.	Carbon Dioxide — Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Jan. 12	9.2	150	10	4.0	0.076	0.092	0.168	0.015	0.012	0.09	10.4	8	85	165	165	330	12.5	.....	...	......	650
" 13	9.2	180	10	4.0	0.104	0.087	0.191	0.019	0.014	0.11	9.8	15	88	165	185	350	12.0	.....	...	......	550
" 14	7.1	160	6	4.1	0.083	0.067	0.147	0.020	0.004	0.11	9.0	9	90	160	175	335	11.0	49	9	11.2	600
" 15	7.1	170	7	4.2	0.069	0.086	0.155	0.012	0.002	0.15	9.1	15	85	155	205	360	15.0	43	6	10.4	800
" 16	9.2	220	7	5.1	0.056	0.109	0.165	0.024	0.001	0.05	9.3	22	82	160	265	425	12.5	50	14	10.4	350
" 17	8.3	250	13	5.1	0.071	0.128	0.199	0.031	0.015	0.02	10.3	12	77	155	260	415	24.0	39	5	10.6	60
" 18	8.9	200	17	4.3	0.062	0.095	0.157	0.021	0.013	0.11	9.0	10	73	140	240	380	12.5	49	17	10.3	230
" 19	8.7	200	16	3.9	0.047	0.092	0.139	0.027	0.014	0.04	8.7	7	80	135	235	370	14.0	58	23	10.8	950
" 20	8.0	160	16	4.2	0.050	0.075	0.125	0.026	0.010	0.10	9.0	9	83	140	205	345	5.5	50	14	10.8	1,000
" 21	8.3	170	13	5.9	0.044	0.097	0.141	0.018	0.004	0.08	9.1	5	82	140	210	350	9.0	48	12	10.7	700
" 22	8.2	150	16	4.9	0.065	0.069	0.134	0.022	0.005	0.11	9.0	9	83	155	175	330	5.5	42	6	10.4	800
" 23	8.8	160	15	5.1	0.058	0.087	0.145	0.021	0.005	0.08	9.1	7	80	145	195	340	8.5	70	35	10.4	700
" 24	9.1	160	14	4.8	0.063	0.087	0.150	0.014	0.004	0.14	9.1	18	76	140	200	340	6.0	81	48	10.8	500
" 25	8.7	170	12	4.8	0.055	0.082	0.137	0.025	0.008	0.07	10.0	13	77	130	210	340	5.0	54	20	10.7	600
" 26	8.9	180	13	5.5	0.055	0.078	0.133	0.025	0.009	0.05	10.5	13	81	140	230	370	5.5	66	30	10.5	600
" 27	9.4	190	12	5.7	0.045	0.120	0.165	0.015	0.011	0.07	9.7	10	81	145	285	430	10.5	62	26	9.9	650
" 28	9.0	210	13	5.9	0.066	0.105	0.171	0.006	0.012	0.08	9.5	12	84	140	325	465	12.5	69	32	10.3	600
" 29	9.3	200	12	5.4	0.051	0.116	0.167	0.017	0.016	0.11	8.5	11	85	135	345	480	14.0	65	28	10.5	600
" 30	9.4	260	11	5.9	0.039	0.152	0.191	0.014	0.021	0.05	7.5	8	74	135	390	525	12.5	78	45	10.3	1,000
" 31	9.3	280	12	6.5	0.024	0.171	0.195	0.014	0.019	0.07	7.7	14	72	120	455	575	13.5	76	44	10.5	1,900
Feb. 1	9.1	260	11	6.2	0.029	0.175	0.204	0.012	0.014	0.13	7.7	13	75	115	455	570	16.0	61	28	9.9	1,100
" 2	10.0	270	11	6.6	0.104	0.106	0.210	0.013	0.019	0.17	7.5	13	71	110	415	525	15.5	54	23	9.7	1,100
" 3	10.2	250	10	5.6	0.046	0.154	0.200	0.008	0.019	0.09	7.6	13	62	105	380	485	12.5	68	41	8.8	1,800
" 4	9.2	270	11	5.8	0.036	0.142	0.178	0.009	0.016	0.07	7.5	13	65	105	370	475	10.5	65	36	10.9	4,200
" 5	8.7	260	11	5.5	0.045	0.125	0.170	0.013	0.017	0.11	7.4	11	65	115	315	430	13.0	71	42	10.6	3,800
" 6	8.8	230	12	5.6	0.070	0.149	0.219	0.012	0.018	0.11	7.9	12	68	125	285	410	15.0	59	29	10.3	4,300
" 7	8.9	210	13	4.9	0.051	0.130	0.181	0.010	0.018	0.09	7.9	16	68	125	250	375	14.0	60	30	10.2	4,800
" 8	9.9	220	11	4.7	0.065	0.118	0.183	0.011	0.017	0.23	7.4	17	66	120	250	370	14.5	77	48	10.8	6,000
" 9	8.4	200	12	5.1	0.060	0.125	0.185	0.009	0.016	0.21	7.5	15	67	120	245	365	12.5	59	30	10.8	2,300
" 10	8.1	210	12	5.1	0.057	0.117	0.174	0.013	0.014	0.23	7.9	16	65	125	255	380	16.5	69	40	10.7	2,500
" 11	8.2	210	10	5.9	0.060	0.122	0.182	0.016	0.013	0.15	8.6	23	69	130	265	395	16.0	54	24	10.7	2,100

Feb. 12	8.2	220	11	5.9	0.058	0.147	0.205	0.015	0.014	0.19	9.9	16	70	125	290	415	13.5	71	40	11.2	4,500
" 13	8.0	220	13	5.0	0.051	0.118	0.169	0.010	0.012	0.22	10.0	15	70	125	270	395	13.0	80	49	11.0	3,400
" 14	7.8	210	12	5.0	0.070	0.136	0.206	0.012	0.013	0.23	9.3	13	71	130	295	425	14.5	90	59	10.3	....
" 15	7.8	210	14	5.1	0.046	0.158	0.204	0.011	0.012	0.14	8.8	16	73	125	275	400	11.5	87	55	10.8	....
" 16	7.6	210	13	5.0	0.068	0.136	0.204	0.012	0.013	0.12	8.8	17	72	120	275	395	14.0	102	70	10.6	....
" 17	7.7	220	13	5.7	0.044	0.129	0.173	0.016	0.009	0.11	7.5	16	74	130	275	405	14.0	69	36	10.0	....
" 18	7.6	210	14	5.1	0.036	0.135	0.171	0.017	0.009	0.11	8.9	16	79	130	290	420	14.5	63	28	10.4	3,100
" 19	7.0	230	12	5.0	0.050	0.135	0.185	0.015	0.006	0.26	9.1	10	81	150	285	435	16.5	71	35	11.1	3,000
" 20	6.9	230	12	5.1	0.050	0.152	0.202	0.007	0.016	0.22	8.0	11	76	140	290	430	13.5	75	42	11.5	2,800
" 21	7.0	220	12	6.0	0.060	0.131	0.191	0.013	0.004	0.11	7.3	12	69	140	280	420	17.5	55	25	11.1	2,000
" 22	7.3	220	12	5.6	0.062	0.142	0.204	0.015	0.008	0.24	7.8	12	71	135	290	425	17.5	58	22	11.2	1,200
" 23	7.3	250	12	6.3	0.061	0.216	0.277	0.018	0.009	0.11	9.0	22	71	135	360	495	20.0	71	40	11.0	1,200
" 24	7.2	260	12	5.7	0.071	0.173	0.244	0.020	0.008	0.09	8.7	15	71	135	310	445	16.5	57	27	10.9	2,200
" 25	7.3	240	11	6.2	0.043	0.159	0.202	0.013	0.008	0.10	9.3	15	68	135	285	420	19.5	55	25	11.2	3,200
" 26	7.0	230	10	5.9	0.050	0.141	0.191	0.012	0.005	0.14	9.3	17	67	140	255	395	15.5	66	37	11.5	3,800
" 27	7.0	210	10	5.4	0.075	0.116	0.191	0.014	0.005	0.18	10.5	13	67	135	240	375	14.0	57	28	10.6	2,800
" 28	7.4	190	12	4.8	0.055	0.126	0.181	0.017	0.005	0.16	9.9	14	67	135	205	340	15.5	77	48	11.5	1,700
Mch. 1	7.7	190	12	4.9	0.049	0.125	0.174	0.014	0.006	0.10	9.2	9	68	135	215	350	15.0	66	36	11.0	1,400
" 2	7.6	190	12	4.9	0.043	0.090	0.133	0.011	0.006	0.16	8.8	10	67	125	210	335	12.0	52	23	11.0	1,600
" 3	9.0	180	14	4.6	0.070	0.110	0.180	0.019	0.007	0.21	8.4	10	68	130	190	320	13.5	68	38	11.5	2,400
" 4	9.0	180	12	5.0	0.055	0.113	0.168	0.020	0.006	0.09	8.6	12	70	130	225	355	16.0	73	42	10.8	1,500
" 5	8.4	210	14	5.0	0.045	0.164	0.209	0.014	0.006	0.10	8.9	10	71	130	260	390	14.0	53	22	11.3	1,100
" 6	8.3	180	11	4.3	0.036	0.095	0.131	0.010	0.006	0.14	8.6	11	72	130	210	340	12.5	107	75	11.3	1,000
" 7	9.0	180	13	4.5	0.049	0.091	0.140	0.012	0.005	0.14	9.0	12	76	135	180	315	10.0	72	39	11.1	750
" 8	9.8	170	13	4.7	0.047	0.073	0.120	0.015	0.006	0.10	8.7	11	76	145	155	300	12.5	82	49	10.9	800
" 9	11.4	200	13	5.2	0.053	0.128	0.181	0.011	0.008	0.10	9.0	9	76	130	230	360	10.0	69	36	10.8	950
" 10	10.5	180	14	5.0	0.056	0.122	0.178	0.014	0.006	0.12	9.4	11	81	135	165	300	9.0	45	9	10.2	600
" 11	10.5	160	14	4.3	0.053	0.099	0.152	0.013	0.006	0.09	9.0	11	82	135	140	275	9.5	60	24	10.6	600
" 12	11.8	150	14	4.7	0.067	0.091	0.158	0.019	0.007	0.14	9.5	11	85	135	150	285	10.5	56	19	10.5	700
" 13	11.0	140	14	4.0	0.043	0.082	0.125	0.018	0.007	0.06	9.0	10	88	135	150	285	10.0	61	22	10.3	800
" 14	11.0	130	14	3.7	0.049	0.051	0.100	0.019	0.007	0.09	9.8	12	87	135	140	275	10.0	93	55	9.9	750
" 15	11.0	130	14	3.7	0.074	0.037	0.111	0.020	0.007	0.07	10.3	12	91	135	140	275	10.0	67	27	10.1	600
" 16	11.0	110	12	4.1	0.044	0.052	0.096	0.011	0.010	0.08	10.4	11	97	145	115	260	9.5	68	25	9.9	500
" 17	11.9	110	12	3.9	0.047	0.053	0.100	0.012	0.012	0.10	11.4	9	97	160	90	250	10.0	57	14	9.9	700
" 18	12.0	120	11	4.0	0.051	0.082	0.133	0.010	0.014	0.12	12.0	10	102	170	105	275	10.0	71	26	10.3	1,100
" 19	12.0	150	12	4.9	0.056	0.062	0.118	0.009	0.014	0.06	12.6	14	104	170	240	410	11.0	88	42	10.1	800
" 20	11.4	170	11	4.7	0.037	0.077	0.114	0.010	0.012	0.08	13.5	11	106	175	205	380	17.5	61	14	10.1	900
" 21	11.7	210	12	5.4	0.039	0.111	0.150	0.009	0.014	0.10	13.6	9	110	185	285	470	15.5	97	49	10.4	1,600
" 22	11.3	300	12	6.0	0.036	0.154	0.190	0.010	0.016	0.07	18.0	12	107	185	405	590	17.5	121	74	10.3	800
" 23	12.5	500	13	8.5	0.034	0.291	0.325	0.018	0.017	0.06	13.9	8	93	165	715	880	22.0	63	22	9.8	Liq.
" 24	12.0	525	12	8.5	0.047	0.218	0.265	0.018	0.019	0.06	11.0	9	92	160	670	830	23.0	69	29	9.5	3,000
" 25	11.7	625	11	9.3	0.052	0.373	0.425	0.006	0.014	0.10	10.1	13	91	160	815	975	23.5	77	37	9.1	6,500
" 26	11.2	825	12	12.0	0.073	0.487	0.560	0.006	0.003	0.15	9.4	12	86	155	1,010	1,165	24.0	56	18	7.5	6,500
" 27	12.0	950	13	13.0	0.053	0.477	0.530	0.016	0.002	0.18	9.1	18	78	155	1,100	1,255	24.0	62	28	8.6	6,000
" 28	11.8	975	14	14.0	0.082	0.498	0.580	0.015	0.001	0.22	8.3	14	73	150	1,250	1,400	25.0	59	27	7.6	3,800
" 29	12.0	1000	13	14.3	0.063	0.507	0.570	0.008	0.001	0.15	7.3	16	74	135	1,200	1,330	24.0	39	6	8.1	1,400
" 30	12.2	1000	14	14.4	0.079	0.598	0.677	0.007	0.002	0.17	6.3	13	69	130	1,120	1,250	24.5	53	23	8.4	2,900
" 31	12.2	950	13	14.2	0.085	0.582	0.667	0.003	0.002	0.14	6.0	14	71	130	1,100	1,230	28.0	50	19	8.3	Liq.
Apr. 1	12.5	900	13	13.0	0.095	0.482	0.577	0.008	0.002	0.13	8.0	16	72	135	930	1,065	27.0	47	15	8.4	5,000
" 2	12.2	750	14	12.7	0.079	0.268	0.347	0.002	0.003	0.18	7.7	18	71	140	815	955	28.0	47	16	8.4	4,800
" 3	12.3	675	14	12.5	0.068	0.429	0.497	0.005	0.002	0.23	7.7	20	66	125	780	905	24.0	53	24	8.4	4,000

TABLE NO. XXII.—Continued.—*Composition of the Mississippi River Water.*

Date. 1901	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, Dissolved.	Residues on Evaporation, Suspended.	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Apr. 4	12.2	650	12	12.2	0.078	0.389	0.467	0.005	0.002	0.11	7.8	19	66	125	805	930	23.0	54	25	8.5	4,500
" 5	12.7	650	13	11.8	0.088	0.289	0.377	0.006	0.001	0.15	7.0	24	69	130	745	875	23.0	46	16	8.0	3,800
" 6	13.0	650	13	11.4	0.077	0.422	0.499	0.005	0.002	0.23	6.7	17	67	130	640	770	24.0	58	29	8.7	3,200
" 7	12.0	600	14	11.0	0.091	0.326	0.417	0.004	0.001	0.19	6.7	19	70	125	610	735	26.0	39	8	8.3	3,200
" 8	12.0	625	14	11.0	0.069	0.388	0.457	0.006	0.001	0.15	6.6	18	67	130	670	800	25.0	42	13	8.6	4,300
" 9	12.0	725	14	13.0	0.072	0.475	0.547	0.002	0.001	0.16	6.4	14	71	130	695	825	25.0	64	33	8.1	5,100
" 10	12.5	675	15	12.4	0.096	0.389	0.485	0.004	0.002	0.11	6.4	18	73	130	680	810	30.0	59	27	8.6	4,700
" 11	12.3	625	16	12.1	0.079	0.391	0.470	0.003	0.001	0.25	6.3	17	75	125	695	820	32.5	74	41	7.5	3,600
" 12	13.0	550	16	11.8	0.065	0.355	0.420	0.003	0.000	0.49	6.5	15	74	130	620	750	20.0	60	27	8.8	2,300
" 13	13.0	600	...	...	...	...	...	...	0.001	...	...	14	74	125	785	860	...	...	...	...	4,400
" 14	13.0	475	...	...	...	...	...	...	0.001	...	...	12	69	130	650	780	...	...	...	...	3,900
" 15	13.0	450	15	10.4	0.095	0.275	0.370	0.005	0.001	0.16	6.7	17	70	125	645	770	21.0	51	20	8.0	3,500
" 16	13.1	600	...	...	...	...	...	...	...	...	...	...	71	125	645	770	...	...	...	...	3,400
" 17	13.3	600	11	10.2	0.063	0.342	0.405	0.006	0.000	0.13	8.5	16	70	125	720	845	30.0	33	2	8.3	Liq.
" 18	13.4	575	...	...	...	...	...	...	...	...	...	...	71	125	850	975	...	...	...	...	4,000
" 19	13.5	600	12	10.0	0.078	0.327	0.405	0.012	0.000	0.08	6.4	12	70	120	795	915	37.0	44	13	8.8	2,500
" 20	13.6	600	...	...	...	...	...	...	...	...	...	...	74	120	730	850	...	...	...	...	3,900
" 21	13.7	550	...	...	...	...	...	...	...	...	...	...	75	125	605	730	...	...	...	...	3,100
" 22	13.2	525	12	9.5	0.078	0.287	0.365	0.005	0.000	0.12	6.4	15	73	110	645	755	37.0	25	0	8.1	2,200
" 23	15.7	525	...	...	...	...	...	...	...	...	...	...	73	120	530	650	...	...	...	...	1,700
" 24	14.4	575	12	8.7	0.070	0.265	0.335	0.005	0.000	0.07	6.5	19	72	120	605	725	29.0	56	24	7.8	2,800
" 25	15.0	625	...	...	...	...	...	...	...	...	...	...	73	125	620	745	...	...	...	...	3,700
" 26	15.0	650	12	9.9	0.054	0.366	0.420	0.006	0.000	0.09	6.1	15	70	125	690	815	36.0	...	...	8.1	3,700
" 27	17.0	675	...	...	...	...	...	...	...	...	...	...	70	120	805	925	...	...	...	...	3,100
" 28	17.5	700	...	...	...	...	...	...	...	...	...	...	73	120	800	920	...	...	...	...	4,100
" 29	18.0	775	...	...	...	...	...	...	...	...	...	...	75	120	835	955	...	...	...	...	3,400
" 30	15.0	725	12	11.2	0.070	0.345	0.415	0.005	0.000	0.18	8.8	16	74	130	805	935	15.0	74	41	7.7	2,400
May 1	17.0	725	...	...	...	...	...	...	...	...	...	...	79	135	755	890	...	...	...	...	4,600
" 2	17.0	700	...	...	...	...	...	...	...	...	...	...	78	140	745	885	...	...	...	...	3,000
" 3	17.5	700	13	10.5	0.054	0.386	0.440	0.008	0.000	0.11	6.8	11	77	135	740	875	14.0	74	40	...	2,800
" 4	18.0	650	...	...	...	...	...	...	...	...	...	...	76	140	620	760	...	...	...	...	3,400

May 5	18.0	600	...	...	...	...	...	...	...	...			77	140	590	780		...		...	2,100
" 6	18.0	550	...	...	...	...	...	...	...	...			75	180	490	620				...	1,600
" 7	18.0	575	12	7.7	0.045	0.247	0.292	0.009	0.000	0.09	8.4	9	76	135	480	615	13.0	88	55	6.7	1,400
" 8	18.0	525	...	...	...	...	...	...	...	...			73	130	515	645				...	2,600
" 9	18.0	525	...	...	...	...	...	...	...	...			71	135	485	620				...	3,300
" 10	18.0	500	13	6.4	0.050	0.207	0.257	0.009	0.000	0.05	7.2	7	61	120	445	565	12.0	52	24	7.2	2,100
" 11	18.0	525	...	...	...	...	...	...	...	...			65	120	440	560				...	3,000
" 12	18.0	500	...	...	...	...	...	...	...	...			67	120	510	630				...	4,500
" 13	19.0	475	...	...	...	...	...	...	...	...			66	120	450	570				...	1,700
" 14	18.6	400	12	5.8	0.057	0.188	0.245	0.009	0.001	0.13	6.7	8	65	120	430	550	1.0	41	12	6.3	1,800
" 15	19.6	400	...	...	...	...	...	...	...	...			67	120	405	525				...	2,400
" 16	19.6	400	...	...	...	...	...	...	...	...			64	120	415	535				...	2,200
" 17	19.9	375	12	6.7	0.069	0.129	0.198	0.006	0.000	0.17	6.8	8	65	125	385	510	12.5	62	33	6.2	1,000
" 18	20.0	350	...	...	...	...	...	...	...	...			68	120	375	495				...	2,300
" 19	20.0	325	...	...	...	...	...	...	...	...			68	120	325	445				...	1,700
" 20	20.4	325	...	...	...	...	...	...	...	...			69	120	375	495					1,200
" 21	20.9	300	13	5.8	0.069	0.130	0.199	0.006	0.000	0.09	9.0	10	73	135	350	485	.5	60	28	6.3	1,000
" 22	20.7	280	...	...	...	...	...	...	...	...			74	150	300	450				...	1,100
" 23	21.3	260	...	...	...	...	...	...	...	...			75	155	315	470					1,200
" 24	21.3	260	14	6.0	0.054	0.112	0.166	0.007	0.000	0.05	15.6	8	80	160	305	465	12.0	57	22	6.2	1,300
" 25	21.7	250	...	...	...	...	...	...	...	...			88	155	325	480				...	2,200
" 26	21.2	270	...	...	...	...	...	...	...	...			84	150	330	480				...	2,500
" 27	21.8	260	...		...	...	...	...	...	...			85	160	310	470					3,200
" 28	22.0	270	15	6.5	0.089	0.113	0.202	0.003	0.000	0.19	12.9	9	87	160	315	475	14.0	48	10	7.0	1,800
" 29	22.2	250			...	...	...	...	...	...			92	155	325	480					1,200
" 30	22.0	300			...		...	...	...	...			98	155	335	490					1,500
" 31	22.4	300	16	6.8	0.056	0.155	0.211	0.008	0.000	0.19	11.0	9	92	160	335	495	12.5	110	70	10.4	1,000
June 1	22.5	375			...	...	...	...	...	...			96	160	385	545					1,400
" 2	22.2	525			...	...	...	...	...	...			100	160	545	705					3,600
" 3	22.5	425			...	...	...	...	...	...			102	175	445	620					1,400
" 4	22.7	600	15	8.8	0.069	0.288	0.357	0.004	0.000	0.21	20.9	14	98	185	670	855	20.0	86	43	7.5	2,500
" 5	23.0	625			...	...	...	...	...	...			96	170	635	805					3,400
" 6	23.0	550			...	...	...	...	...	...			96	160	525	685					2,900
" 7	23.2	525	15	8.3	0.068	0.211	0.279	0.006	0.000	0.09	15.3	11	95	165	540	705	24.0	96	54	7.5	3,000
" 8	23.3	500			...	...	...	...	...	...			98	175	520	695				...	2,800
" 9	23.0	500			...	...	...	...	...	...			93	165	485	650				...	3,300
" 10	23.4	425			...	...	...	...	...	...			87	165	455	620					2,100
" 11	23.4	500	14	7.2	0.038	0.208	0.246	0.002	0.000	0.08	15.3	8	83	160	480	640	22.5	69	32	7.1	2,800
" 12	23.8	450			...	...	...	...	...	...			76	145	460	605				...	3,100
" 13	23.8	400			...	...	...	...	...	...			72	135	415	550				...	2,200
" 14	24.2	450	10	7.2	0.037	0.190	0.227	0.008	0.000	0.06	11.1	9	71	140	430	570	21.0	44	13	6.8	1,400
" 15	24.9	475			...	...	...	...	...	...			72	135	450	585				...	1,200
" 16	25.0	450			...	...	...	...	...	...			71	140	450	590				...	1,600
" 17	25.4	450			...	...	...	...	...	...			70	140	390	530				...	950
" 18	25.8	400			...	...	...	...	...	...			71	135	385	520				...	800
" 19	25.0	350	11	6.4	0.039	0.157	0.196	0.006	0.000	0.04	13.5	9	72	135	360	495	24.5	39	7	...	1,200
" 20	26.2	350			...	...	...	...	...	...			71	140	390	530				...	1,300
" 21	26.6	400	10	7.0	0.044	0.152	0.196	0.005	0.000	0.17	13.9	12	72	140	445	585	21.0	95	63	8.6	950
" 22	26.8	400			...	...	...	...	...	...			72	150	395	545				...	1,200
" 23	26.6	375			...	...	...	...	...	...			74	155	355	510				...	1,600
" 24	26.8	400			...	...	...	...	...	...			75	150	375	525				...	2,000

TABLE No. XXII.—Continued.—*Composition of the Mississippi River Water.*

Date.	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved.	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, * Dissolved.	Residues on Evaporation, Suspended.	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
1901																					
June 25	27.0	400	10	6.9	0.030	0.144	0.174	0.006	0.000	0.25	14.3	16	77	160	445	605	23.0	53	19	5.8	2,400
" 26	27.9	450	...	...	...	...	...	...	...	...	...	...	79	175	525	700	...	...	...	...	2,200
" 27	27.2	475	...	...	...	...	...	...	...	...	...	...	72	165	570	735	...	...	...	...	2,100
" 28	27.6	550	10	7.9	0.034	0.207	0.241	0.003	0.000	0.08	14.4	14	83	175	590	765	24.5	50	13	5.3	2,000
" 29	27.9	475	...		...	...	...	...	...	...	...	...	83	180	465	645	...	...	...	...	1,400
" 30	28.0	450	...	...	...	...	...	...	...	...	...	...	84	185	485	670	...	...	...	...	1,400
July 1	28.2	450	...	...	...	...	...	...	...	...	...	...	85	185	415	600	...	...	...	...	1,100
" 2	28.5	500	10	6.8	0.041	0.217	0.258	0.000	0.001	0.08	12.0	12	83	185	570	755	19.0	58	21	6.6	2,600
" 3	28.7	550	...	...	...	...	...	...	...	...	...	...	86	185	560	745	...	...	...	...	1,500
" 4	28.8	450	...	...	...	...	...	...	...	...	...	...	85	165	435	600	...	...	...	...	1,600
" 5	28.9	450	11	6.8	0.066	0.184	0.250	0.006	0.001	0.07	10.4	9	84	165	440	605	17.5	75	38	6.0	1,800
" 6	29.0	500	...	...	...	...	...	...	...	...	...	...	85	180	570	750	...	...	...	...	1,600
" 7	29.0	575	...	...	...	...	...	...	...	...	...	...	81	185	695	880	...	...	...	...	2,000
" 8	29.0	550	...	...	...	...	...	...	...	...	...	...	82	170	660	830	...	...	...	...	1,000
" 9	29.5	650	12	9.9	0.044	0.224	0.268	0.007	0.000	0.07	10.2	12	85	170	820	990	25.0	58	21	6.3	2,000
" 10	29.9	675	...	...	...	...	...	...	...	...	...	...	83	185	805	990	...	...	...	...	1,900
" 11	29.8	725	...	...	...	...	...	...	...	...		...	82	180	765	945	...	...	...	...	1,600
" 12	30.2	700	11	9.2	0.058	0.240	0.298	0.008	0.000	...	9.6	17	81	175	685	860	25.5	51	15	5.8	1,600
" 13	30.2	725	...	...	...	...	...	...	...	...	...		80	180	800	980	...	...	...	...	1,600
" 14	30.5	725	...	...	...	...	...	...	...	...	...	...	80	175	850	1,025	...	...	...	...	1,600
" 15	30.2	700	...	...	...	...	...	...	...	...	...	...	79	185	825	1,010	...	...	...	...	1,300
" 16	29.9	700	12	8.8	0.059	0.234	0.293	0.005	0.000	0.09	8.5	23	78	170	735	905	29.0	37	3	9.1	3,300
" 17	30.0	775	...	...	...	...	...	...	...	...	...	...	77	205	890	1,095	...	...	...	...	1,400
" 18	29.8	750	...	...	...	...	...	...	...	...		...	77	175	785	960	...	...	...	...	2,400
" 19	29.5	675	12	7.8	0.038	0.186	0.224	0.004	0.001	0.13	7.1	24	78	180	650	830	27.5	27	0	5.6	2,200
" 20	30.0	550	...	...	...	...	...	...	...	...	7.4	...	80	190	465	655	...	...	...		2,200
" 21	29.5	475	...	...	...	...	...	...	...	...	...	...	80	185	345	530	...	...	...	...	1,500
" 22	29.3	450	...	...	...	...	...	...	...	...	...	...	82	180	520	700	...	...	...	...	1,400
" 23	29.5	350	12	6.7	0.060	0.054	0.114	0.003	0.001	0.06	7.6	17	84	180	265	445	7.5	37	0	6.5	2,500
" 24	28.9	325	...	...	...	...	...	...	...	...	...	...	85	170	255	425	...	...	...	...	2,100
" 25	29.0	325	...	...	...	...	...	...	...	...	...	...	87	175	255	430	...	...	...	...	1,400

" 26	28.9	400	11	4.4	[illegible]	0.106	0.184	0.010	0.000	0.27	8.0	19	89	170	315	485	9.0	57	18	6.5	4,100
" 27	28.7	350	...	...	...	...	...	...	...	...	...	...	89	190	285	475	...	...	...	...	1,000
" 28	28.8	250	...	...	...	...	...	...	...	...	...	...	92	185	215	400	...	...	...	...	1,800
" 29	29.0	260	...	...	...	...	...	...	...	...	...	...	91	190	180	370	...	...	...	...	1,200
" 30	28.9	220	12	3.7	0.056	0.057	0.113	0.003	0.002	0.48	8.5	...	94	200	175	375	7.5	26	0	8.0	2,200
" 31	29.2	190	...	...	...	...	...	...	...	...	...	...	95	195	115	310	...	...	...	...	1,300
Aug. 1	29.0	160	...	...	...	...	...	...	...	...	...	...	95	205	115	320	...	...	...	...	1,100
" 2	29.2	160	12	3.0	0.044	0.028	0.072	0.007	0.001	0.11	8.3	...	93	215	120	335	5.5	...	...	6.1	900
" 3	29.9	160	...		...	...	...	...	...	...	...	...	95	210	140	350	...	...	...	...	850
" 4	29.8	160	...	...	...	...	...	...	...	...	...	...	98	230	95	325	...	...	...	...	Liq.
" 5	29.7	130	...	...	...	...	...	...	...	...	...	...	99	235	85	320	...	...	...	...	Liq.
" 6	29.8	150	11	2.9	0.049	0.036	0.085	0.003	0.002	0.15	8.3	...	99	250	90	340	15.0	33	0	5.7	800
" 7	29.9	130	...	...	...	...	...	...	...	...	...	...	103	245	75	320	...	...	...	...	1,100
" 8	30.0	120	...	...	...	...	...	...	...	...	...	...	100	220	85	305	...	...	...	...	700
" 9	30.1	120	12	3.6	0.036	0.018	0.054	0.001	0.002	0.25	9.1	...	100	See Note.			5.0	50	6	6.3	900
" 10	30.0	110	...	...	...	...	...	...	...	...	...	...	104				...	...	...	...	1,500
" 11	29.9	130	...	...	...	...	...	...	...	...	...	...	104				...	...	...	...	1,200
" 12	30.5	110	...	...	...	...	...	...	...	...	...	...	109				...	...	...	...	450
" 13	30.0	95	10	6.5	0.046	0.015	0.061	0.005	0.001	0.23	9.1	...	112				7.5	56	7	6.4	230
" 14	29.8	90	...	...	...	...	...	...	...	...	...	...	113				...	...	...	...	350
" 15	29.0	150	...	...	...	...	...	...	...	...	...	...	111				...	...	...	...	475
" 16	28.5	140	13	5.0	0.039	0.028	0.067	0.003	0.002	0.29	9.9	...	114	...	...	...	9.5	57	7	5.8	650
" 17	29.5	110	...	...	...	...	...	...	...	...	...	...	115	...	...	...	...	...	...	...	875

NOTE.—Analytical work was stopped because of the excessive humidity of the atmosphere, making accurate weighings impossible.

TABLE No. XXIII.—*Results of Partial Mineral Analyses of the Mississippi River Water.*

Number of Portions, in Average Sample.	Period Represented by Sample. 1900-1901.	PARTS PER MILLION.										
		Residue on Evaporation.	Silica, SiO_2.	Sulphates, SO_4.	Carbon Dioxide, Free and Half-Bound, CO_2.	Chlorine, Cl.	Nitrogen as Nitrates.	Aluminum, Al.	Iron, Fe.	Calcium, Ca.	Magnesium, Mg.	Alkalinity, $Ca.CO_3$.
21	Dec. 10-16	155	12.50	....	.....	6.90	0.17	1.07	Trace.	29.06	6.78	69
21	Dec. 17-23	110	10.60	13.93	.....	8.08	0.30	2.24	Trace.	35.61	8.02	62
18	Dec. 24-30	155	11.95	17.20	.....	6.78	0.24	0.81	Trace.	26.18	6.16	70
21	Dec. 31-Jan. 6	160	10.60	18.05	.....	8.90	0.17	1.37	Trace.	26.95	6.89	73
18	Jan. 7-12	155	9.45	13.48	.....	10.35	0.16	2.47	0.03	25.11	7.09	77
18	Jan. 13-18	155	8.55	14.54	46	9.40	0.11	0.45	Trace.	28.35	8.20	83
21	Jan. 19-25	140	11.00	10.02	58	8.65	0.09	0.61	Trace.	29.11	7.17	80
21	Jan. 26-Feb. 1	135	8.00	15.13	68	8.30	0.08	0.40	Trace.	27.65	6.89	79
21	Feb. 2- 8	115	6.75	19.89	65	8.00	0.12	0.56	Trace.	25.71	6.02	62
21	Feb. 9-15	125	6.80	16.23	73	8.85	0.19	0.35	Trace.	24.15	6.33	69
21	Feb. 16-22	135	6.60	17.60	70	8.25	0.17	0.62	Trace.	31.60	6.73	75
21	Feb. 23-Mar. 1	135	11.45	14.96	64	9.40	0.13	0.72	Trace.	25.07	5.99	68
21	Mar. 2- 8	130	8.60	16.40	73	8.50	0.13	0.48	Trace.	25.60	6.70	71
21	Mar. 9-15	135	8.30	13.56	66	8.85	0.10	0.69	Trace.	29.28	8.11	84
21	Mar. 16-22	170	6.25	18.41	80	13.40	0.09	0.51	Trace.	34.75	9.84	103
21	Mar. 23-29	155	5.45	18.33	61	9.50	0.13	0.51	Trace.	28.93	8.08	84
96	Mar. 30-Apr. 30	125	5.90	18.95	51	7.10	0.17	0.64	Trace.	26.89	6.45	71
93	May 1-31	135	8.85	17.80	66	10.40	0.12	0.90	Trace.	28.18	6.65	75
96	June 1-30	165	10.05	26.30	66	14.45	0.14	3.55	Trace.	31.05	7.31	82
93	July 1-31	180	9.50	30.94	48	9.60	0.16	0.67	Trace.	33.93	7.98	84

NOTES.—No determinations of Sodium or Potassium were made.

The suspended matter was removed from the samples by filtration through a washed Berkfeldt filter-tube. Therefore, the determinations are those of the dissolved constituents.

Biological Character of the Mississippi River Water.

BACTERIAL FLORA.

Quantitative.—The numbers of bacteria were determined in each of three samples daily, and the averages of these three determinations are recorded in the foregoing tables. It is evident that the numbers of bacteria contained in the Mississippi River water are low in comparison with those contained in the water of some other clay-bearing streams, and in the water of some of the upper tributaries, especially the Ohio.

Qualitative—The most important problem in this connection was the determination of the extent of the occurrence of the normal intestinal bacterium—Bacillus coli communis. Occasionally search was made for the Bacillus enteritidis sporogenes (Klein*), which is said to abound in cultivated soil, and is also said to be associated with cases of severe diarrhœa, especially the diarrhœa of infants. Considerable time was spent in determining the species of the bacterial flora in the river water, and while the work was not exhaustive, nine hitherto undescribed species of bacteria were isolated, and it is believed that the methods† of species differentiation and classification were improved.

In addition to the nine hitherto undescribed forms, several well known species were isolated.

BACILLUS COLI COMMUNIS.

In waters which contain unpurified sewage, the test for this intestinal organism is of the utmost importance. In the Mississippi River at New Orleans, however, there is evidently so much self-purification effected by natural agencies, such as dilution, sedimentation, etc., that this normal intestinal bacillus was one of the least common of the forms isolated. In about 100 tests with volumes of water varying from 1 to 300 cubic centimeters, its presence was demonstrated only three times, although the larger samples of water were concentrated in a centrifuge before being seeded into the media contained in fermentation tubes. Two kinds of media were used in the fermentation tubes, namely, dextrose-broth and dextrose-broth containing 0.15 per cent phenol.

Results.—Fifty per cent of the ordinary broth-cultures and forty per cent of the phenol broth-cultures show the presence of gas-producing bacteria. The amount of gas produced was small, and the amount of carbon dioxid (CO_2), contained therein, never equaled the amount of other gases produced.

BACILLUS ENTERITIDIS SPOROGENES.

As this bacillus is found widely distributed in cultivated soil, its occurrence in a river constantly eroding such large quantities from its

* Medical officers' report in supplement to the report of the British Local Government Board, 1897–8.

† See paper in the Journal of the American Public Health Association, by R. S. Weston and A. I. Kendall, on "Some Common Bacteria in American Streams, including nine species isolated at New Orleans", September, 1901.

banks as does the Mississippi, and receiving from its numerous tributaries water heavily charged with eroded matter, though a matter of importance, is by no means remarkable. Perhaps more remarkable is the fact that the number of times it was found occurring in the river water was so small in proportion to the number of tests for its presence which were made. The species had previously been isolated by the writer in samples of the Red River water at Shreveport, La., during the spring and summer of 1900.

Five out of twelve tests made at New Orleans during January, 1901, showed the presence of these bacteria, 10 cubic centimeters of water being used in each case. After January 30, frequent tests failed to isolate the bacillus from the river water, even when 25 cubic centimeters of water were used for a test.

SPECIES OF BACTERIA ISOLATED.

The bacteria isolated from the Mississippi River water at New Orleans agree in character with the published descriptions of the following species, and are probably identical with, or closely related to them, in so far as the present status of bacterial knowledge will allow. In general, the bacterial flora of the Mississippi River water at New Orleans is characterized by the presence of large numbers of non-pathogenic, fluorescent and liquefying forms, and the absence of gas-producing forms and the forms usually associated with sewage contamination. The names of the species are as follows:

Number.	NAME.		Investigator.
1	Bacillus	fluorescens liquifaciens	Fluegge.
2	"	New Orleans No. 1	
3	"	New Orleans No. 2	
4	"	New Orleans No. 3	
5	"	plicatus	Zimmerman.
6	"	New Orleans No. 4	
7	Sarcina	New Orleans No. 5	
8	Bacillus	New Orleans No. 6	
9	"	violaceus	Frankland.
10	"	mycoides	Fluegge.
11	"	subtilis	Ehrenberg.
12	"	cloacae	Jordan.
13	"	punctatus	Zimmerman.
14	"	enteritidis sporogenes	Klein.
15	"	liquidus	Frankland.
16	"	New Orleans No. 7	
17	"	New Orleans No. 8	
18	"	coli communis	Escherich.
19	"	proteus zopfii	Hauser.
20	"	New Orleans No. 9	

It will be noticed that no names are given to the hitherto undescribed species which are designated as "New Orleans, Nos. 1 to 9"; these species are described elsewhere.*

MICROSCOPICAL FLORA AND FAUNA.

The turbidity of the water was so great during the period of this investigation that little opportunity was offered for the growth of algæ and diatoms, but when the water was allowed to subside in the basins, growths of tetraspora, oscillaria, draparnaldia and chætophora collected about the margins of the water surfaces. Practically, no free swimming forms were found. Eggs of rotifera and crustacea were observed during the winter and a few rotifera, cyclops, daphniæ, bosminæ and common shrimp appeared during the spring. A few aquatic insects, snails and small fish also found their way into the basins at different times during the investigation.

RELATIVE PURITY OF THE MISSISSIPPI RIVER WATER AT NEW ORLEANS, WHEN COMPARED WITH OTHER AMERICAN RIVERS.

From what goes before it will be seen that the Mississippi River at New Orleans, as evidenced by the data obtained during this investigation, is unusually pure from a sanitary standpoint. For instance, it is believed that if 100 cubic centimeter samples of water were taken from the Merrimac at Lawrence, the Hudson below the Mohawk, the Schuylkill, the Potomac, the Ohio at Cincinnati, they would show the presence of Bacillus coli communis as a rule. Such is not the case with the Mississippi River water at New Orleans, because, as stated above, the opportunities for natural purification are so great during the last few hundred miles of its flow, and the amount of additional pollution received is so small in comparison to the discharge of the river, that the bacteria which one is accustomed to consider to be the normal inhabitants of surface water apparently crowd out those abnormal bacteria which are carried into the river with the drainage from populated and cultivated areas. It must also be remembered that the banks of the Mississippi, above New Orleans, are protected by levees. These levees also, in turn, protect the river from contamination except where sewers exist. Since it is usually more convenient for the towns immediately above New Orleans to carry their drainage away from the river, almost no local pollution exists.

The chief objections which can be raised against the use of the unpurified Mississippi River water are, therefore, æsthetic, not hygienic. The river carries vast quantities of suspended matter; a million gal-

* Journal American Public Health Association. Report of Buffalo Meeting 1901. loc. cit.

lons, on the average, containing 2.7 tons of dry mud. This means that a purification plant large enough to supply a city like New Orleans would have to remove about 108 tons of mud, on an average, and at times of greatest turbidity would have to remove as much as 435 tons from each day's supply. The mechanical removal of this quantity of suspended matter, in itself, is an engineering problem of considerable magnitude; and the feasibility of the purification of the water is largely dependent upon its economical accomplishment.

It is not known that water containing these amounts of suspended matter causes harm when taken into the system. It is believed that suspended matter, *per se*, is not the direct cause of disease, though it is quite possible that slight digestive derangements of a temporary nature might occur in cases of strangers who drink freely of the water before becoming accustomed to it. On the other hand, the local water has long enjoyed an excellent reputation for healthfulness for use on shipboard.

This suspended matter, however, gives the river water an unsightly appearance and it, therefore, is far from being a satisfactory source of supply, even when æsthetic considerations are forgotten, because the water is so unfit for table, laundry and bathing purposes that the community is forced to use water from cisterns and other sources, which water is not always satisfactory from a hygienic point of view. Thus, indirectly, does the use of this water, itself hygienically unobjectionable, affect the general health of the community.

In a few words, therefore, the Mississippi River water, as a source of supply is objectionable, because it contains large amounts of suspended matter, while the amount of sewage pollution is so slight that it is believed that any system of water purification which will satisfactorily clarify the water from an economical and æsthetic standpoint, will consequently effect a satisfactory purification of the same from a hygienic one.

CLASSIFICATION OF THE WATER.

At times the Misssissippi River water partakes largely of the character of one of its main tributaries, at times of another, while at other times the characteristics of no one stream predominate to any measureable extent. It is possible to divide the water met with in this investigation into classes, crudely, to be sure, according to the character of the predominating tributary, as follows:

CLASS I.—October 1, 1900, to April 26, 1901. This class comprises water which most resembles in character that of the upper tributaries.

This class may further be divided into—

Sub-Class A.—October 1 to December 21, 1900. Water between the beginning and the end of a rise.

Sub-Class B—December 22, 1900, to March 16, 1901. Water of low turbidity.

Sub-Class C.—March 16 to April 26, 1901. Water from the beginning of a rise until the characteristics of Class II predominated.

CLASS II.—April 27 to August 17, 1901. This class comprises water which most resembles the Western tributaries in character.

This class may be further divided into—

Sub-Class A.—May 21 to 31, 1901. Water partaking largely of the character of the streams of the Arkansas basin.

Sub-Class B.—June 1 to 11, 1901. Water partaking largely of the character of the Red River.

The term "Upper tributaries" applies to the streams which unite at Cairo, while the term "Western tributaries" applies to the streams of the Red and Arkansas basins. During August, 1901, there was an abnormal rise of the Ohio River which effected an abnormal rise of the Mississippi at New Orleans, after the close of these investigations.

CHAPTER II.

DESCRIPTION OF THE WATER PURIFICATION STATION.

Location.—The Water Purification Station was located in Au Park on a plot of land adjacent to the Louisiana Experiment S and situated between it and the Mississippi River. Auduboı was selected for the location of the Station on account of its a bility for the public; the easy approach to the river, and the ne of the proposed intake location. Besides, no sewers were kn empty into the river immediately above.

New Orleans has a river front of about 11 miles. Canal st about 3, and Audubon Park about 9, miles above the lower cit The proposed intake location is 2.1 miles above Audubon Park of these distances are along the river front.

GENERAL ARRANGEMENT OF PLANT.

The general arrangement of the plant is shown on Plates I and V. The plant consisted of the following structures:

1. Pump and Intake.
2. Four Subsiding Basins.
3. Three Coagulating Basins.
4. Four Filters; two each of the English and American with appurtenances.
5. Tower Tank.
6. Boiler House.
7. Laboratory.

The general arrangement is briefly described here below. A detailed description is given further along.

Water was constantly pumped from the river into each o subsiding basins, out of which latter it flowed into a filter, in on and into coagulating basins and thence into filters in each of the other cases. Thus there were four separate processes or syst water purification, giving opportunity to study a sufficiently range of conditions as to plain subsidence, coagulation and suppl tary subsidence, and of filtration through beds of sand at a slov as well as of filtration at a high rate, with the aid of coagu through beds of sand which are cleaned by mechanical means.

In the field of water purification the nomenclature is on a unsettled basis at present. Subsiding basins are called sedimen

basins by some, and settling basins by others. The process of filtration, which originated in England seventy years ago, is variously known as English filtration, sand filtration, and also slow filtration; while the other well-known method of filtration, originating in this country, is called American filtration, mechanical filtration and rapid filtration. Each term has its merits and demerits. The terms, English filters and American filters, have been used in most places where investigations have been made upon the purification of very turbid river waters in this country; and, as they are the ones to which the writer is most accustomed, they will be used throughout this report. The full set of devices used to effect the complete purification of the water, comprising subsiding basins, coagulating basins and filters, with their appurtenances, is called a system of purification. These four systems have been called Systems Nos. 1, 2, 3 and 4, respectively.

System No. 1.—The English system provided for three days of plain subsidence, and filtration through about 5 feet of fine sand, supported upon 7 inches of graded gravel, at a rate of 2.56 million gallons per acre per day, the standard German rate.

System No. 2.—The modified English system provided for two days of plain subsidence and one of coagulation, and filtration through about 3 feet of medium sand, supported upon 7 inches of graded gravel, at a rate of 5.2 million gallons per acre per day.

The clogged sand layers of the filters in Systems 1 and 2 were cleansed by draining and scraping the surface of the same.

Systems Nos. 3 and 4.—The American systems were similar. They both provided for plain subsidence: No. 3 for 12 or 48 hours; No. 4 for 12 or 24 hours. They both provided for various periods of coagulation: No. 3, for 0.5, 3.0, 6.0, 9.0, or 12 hours; No. 4 for 0.5, 6.0, 12.0, or 24 hours, and they provided for filtration through about 2.9 feet of sand, at a rate of 125 million gallons per acre per day.

The clogged sand layers in both systems were cleansed by washing the sand in situ by reverse currents of water, agitating the sand in System No. 3 by currents of air, and in System No. 4 by revolving rake arms driven by steam power.

The combined output of the plant in operation (four systems) was about 93,000 gallons of water per 24 hours. Some of this was pumped to the tower tank and became the water supply for the boilers and laboratory, also for washing the American filters, and for refilling the English filters from below after scraping. The boiler plant furnished steam for the necessary machinery and the heating apparatus. There was also an adequate laboratory and office.

A more detailed description of the plant is as follows:

INTAKE AND PUMP.

The intake was constructed of 4-inch pipe, wrought iron from the suction inlet of the pump to the river side of the levee, and cast iron for the remainder of the distance. There was a valve on the outer end of the cast iron pipe; and 25 feet of rubber suction hose with strainer and foot-valve extended beyond this into the river. The end of the suction was constantly held just beneath the surface of the water by a rope attached to a house boat, moored near the shore. The intake was located on a making bank. The levee at the point of intake was 10 feet high. In order to avoid cutting into the levee, or getting an accumulation of air at the top of a syphon, the pump was placed in a raised pump-house, the elevation of the floor of which was the same as that of the top of the levee. Therefore, the suction chamber of the pump was at the highest point in the suction line. This intake was laid with great care. This was necessary because the maximum suction lift, including friction, was 28 feet. The pump was a Worthington Duplex, 6 inches by 5.75 inches by 6 inches in size.

SUBSIDING BASINS.

Concerning the construction of the subsiding basins, four in number, it may be best understood from Plates IV and V, and from the photographs (Plates I and XII) accompanying this report. The subsiding basins had a combined area of 45 by 50 feet; which area was further divided, by partitions, into four different sized basins, each 10 feet deep.

Subsiding Basin No. 1.—This basin was 50 feet long by 10 feet wide by 10 feet deep. It held 36,000 gallons, or three normal days' supply for Filter No. 1.

Subsiding Basin No. 2.—This basin was 50 feet long by 5 feet wide by 10 feet deep. It held 18,000 gallons, or two days' supply for Filter No. 2.

Subsiding Basin No. 3.—This basin was 50 feet long by 20 feet wide by 10 feet deep, and held 72,000 gallons, or two days' supply for Filter No. 3.

Subsiding Basin No. 4.—This basin was 50 feet long by 10 feet wide by 10 feet deep. It held 36,000 gallons, or one day's supply for Filter No. 4.

The basins were constructed of heavy yellow pine timber, which was lined with three-ply tarred paper, overlaid on the sides with two layers of tongued-and-grooved ceiling, and on the bottom with one layer

of tongued-and-grooved flooring. The joints, angles and corners were caulked, and 2-inch by 1-inch pieces were spiked into the angles.

The subsiding basins were not covered.

A 2.5-inch pipe led from the discharge of the main pump to the 2.5-inch header which ran across the tops of the basins at their inlet ends. In this header, opposite to the center of each basin, there were placed tees which connected with the 2.5-inch globe valves and finally with the perpendicular inlet pipes, which latter reached to within 2 feet of the bottom of the basins.

The outlets of the basins were invariably near the surface of the water therein, and consisted usually of several 2-inch holes bored through the partition separating the subsiding and coagulating basins. The outlet of Basin No. 1, however, consisted of two wrought-iron pipes—1-inch and 1.25-inches in diameter, respectively—whose basin ends terminated in two driven well points. These latter were for the purpose of preventing the passage of fish, snails, water beetles, etc., into Filter No. 1.

Each basin was provided with a 2.5-inch washout pipe, which was placed in the floor of each basin, near the outlet of the same.

RE-ARRANGEMENT OF SUBSIDING BASINS.

Between April 11th and May 3d, 1901, the basins were remodeled to some extent, as follows:

Basin No. 1.—This basin had a total capacity of three days' flow and was first arranged so that samples could be taken after three days' subsidence only. It was necessary to increase existing knowledge of the results of one and two days' plain subsidence, respectively; consequently baffles and overflow partitions were placed in the basin at points one-third and two-thirds of the distance from the inlet to the outlet end of the basin, respectively. This permitted the sampling of the water at these points, the samples representing water which had remained in the basin for one and two days, respectively.

Basin No. 2.—This was arranged in a similar manner to Basin No. 1, and one overflow partition or baffle was placed in it so as to permit sampling after 6 hours of plain subsidence.

Basin No. 3.—This basin was transformed from one of 48 hours' into one of 12 hours' capacity by building a tight partition at a point one-quarter of the distance from the inlet to the outlet end of the basin and by by-passing the water from this partition by means of a wooden trough directly to the coagulating basin, thus throwing three-quarters of the basin out of service.

Basin No. 4.—This basin was transformed from one of 24 hours' into one of 12 hours' capacity by building an overflow partition

and baffle across its middle. Thus the part which had been used previously as a subsiding basin became a part of the coagulating basin. On July 9th, another overflow partition and another baffle were placed in the basin in order to permit sampling after 6 hours of plain subsidence.

All of these baffles were constructed of tongued-and-grooved pine sheathing. It was found necessary, however, to cover this sheathing with cotton sheeting to prevent a diffusion of water through the partitions and baffles.

COAGULATING BASINS.

The coagulating basins were three in number, and were constructed of heavy lumber, lined with tarred paper and tongued-and-grooved sheathing, in a manner similar to the subsiding basins. The inlet to each basin was just below the level of the water surface. As the water flowed into each coagulating basin, it crossed a trough made of 0.875-inch by 12-inch boards. These troughs were open on top, and were known as coagulating troughs. Their length was the width of the coagulating basins, and their width was about 10 inches. Their top edges were 2 or 3 inches below the normal level of the water in the coagulating basins. The flow of water was across these troughs. In the bottom of each trough there was a lead coagulant pipe 0.5-inch in diameter. This pipe was drilled with 0.125-inch holes about 6 inches between centers. One end of the pipe was closed with a plug; the other led to a point near the device for feeding the coagulant solution. The coagulant solution was fed at will into any one of these pipes at the desired rate. As the coagulant issued from the small holes in the coagulant pipe, it was taken up by the water as it passed across the trough.

System No. 1.—System No. 1 had no coagulating basin.

System No. 2.—System No. 2 had a coagulating basin of 9,000 gallons, or 24 hours' capacity. It was 25 feet long, 10 feet deep and 5 feet wide. There was a baffle at a point 3 feet distant from the inlet end of the basin, which extended from the top of the basin to within 2 feet of the bottom of the same. This baffle prevented the direct passage of water from the inlet to the outlet.

The outlet of Basin No. 2 first consisted of two wrought iron pipes 1-inch in diameter and 1.25 inches in diameter, respectively, which pipes reached to within 18 inches of the flow line of the basin. These pipes were shortly replaced by strainers, and, on May 1, the strainers were enclosed by a box-weir whose top came to within about 4 inches of the flow line of the water in the basin. During June, July

and August it was necessary to remove the strainers, because the growths of algae in this basin prevented the free passage of water into Filter No. 2.

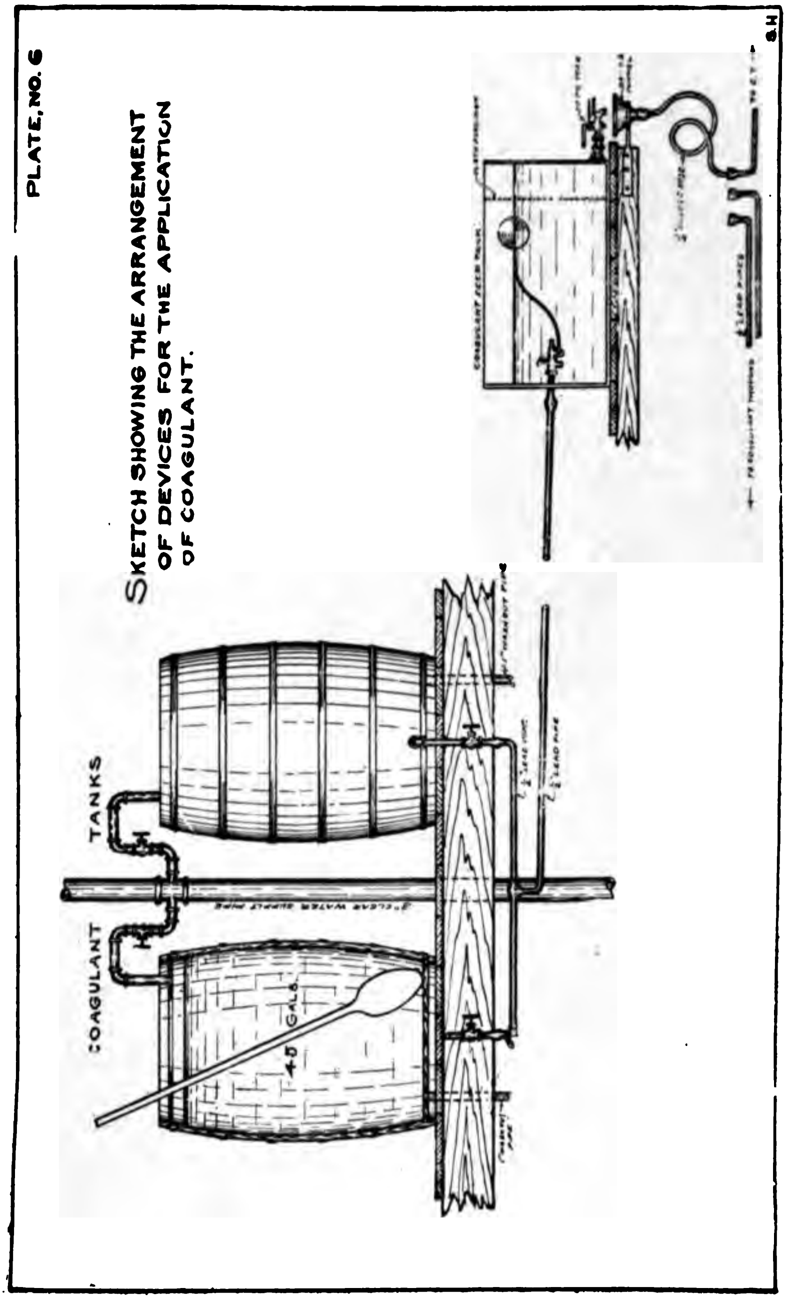
System No. 3—System No. 3 had a coagulating basin of 18,000 gallons, or 12 hours' capacity. It was 25 feet long, 10 feet wide and 10 feet deep. It was divided into five compartments by means of wooden partitions. Each compartment was fitted with a coagulant feed trough containing a coagulant feed pipe. These troughs were located on the side where the water entered the compartment, and, when the inlet and outlet of any compartment were both near the flow-line of the water in the basin, a baffle was constructed to extend from the top of the basin to within 3 feet of the bottom of the same. The point of application of coagulant in the 0.5-hour or final coagulating basin was at its bottom, the stream of coagulant mingling with the stream of water as the latter flowed into the final compartment from the previous one. This arrangement of coagulating troughs and coagulant pipes permitted the addition of coagulant at points equivalent to about 12, 9, 6, 3 and 0.5 hours before filtration, respectively, when the rate of flow through the basins was 25 gallons per minute.

The outlet of this coagulating basin was located in the 0.5-hour or final compartment at a point 2 feet below the normal flow line of the basins.

System No. 4.—Originally this basin was constructed like that of System No. 3, except that it was divided into only three compartments, permitting the application of coagulant at points equivalent to 12, 6 and 0.5 hours before filtration, respectively, when the rate of flow through the basin was 25 gallons per minute.

Between April 23d and May 3d, 1901, however, another partition, baffle and coagulating trough were constructed at a point half way across Subsiding Basin No. 4, which, in conjunction with the already existing coagulating basin, permitted the use of a maximum coagulation period of 24 hours. The period of plain subsidence was correspondingly reduced from 24 to 12 hours by this change.

At first the coagulating basins were covered with a shed roof, but this was removed from Coagulating Basin No. 2 during April, and from Coagulating Basins Nos. 3 and 4 during May. These covers were removed for the purpose of studying the effect of sunlight upon the growth of algæ in the basins.


PLATE, NO. 6
SKETCH SHOWING THE ARRANGEMENT OF DEVICES FOR THE APPLICATION OF COAGULANT.
COAGULANT TANKS
45 GALS.
S.H

DEVICES FOR PREPARING THE CHEMICAL SOLUTIONS, AND FOR DISTRIBUTING THE SAME TO THE POINTS OF APPLICATION.

The general arrangement is shown on Plates IV and V.

Chemical.—Sulphate of alumina was used as a coagulant, and 5 per cent solutions of it, by weight, were invariably prepared.

Chemical Tanks.—Two barrels served as chemical tanks. These barrels were placed on a platform just beneath the tower tank, from which latter they could be readily filled with filtered water. They were provided with depth gauges, to which they were regularly filled. The coagulant was placed in one of the barrels, together with the required quantity of water. After solution, the contents of the barrel were well mixed. One barrel was used as a supply tank while a new solution was being prepared in the other. Washout pipes were provided for each barrel. They were washed out before each new solution was made. A 0.5-inch pipe, provided with a valve, led from each barrel. Both of these terminated in a common tee, which, in turn, connected with the 0.5-inch lead supply pipe, which connected with the feed tanks.

Coagulant Feed Tanks.—There were five of these in use. Three were used for the initial application of coagulant in Systems Nos. 2, 3 and 4, while two were occasionally used for the secondary application of coagulant to the water, 0.5 hour before filtration, in Systems Nos. 3 and 4. A sketch showing the arrangement may be seen on Plate VI.

The feed tanks consisted, briefly, of ball-cock tanks supplied with solution from the barrels through the lead pipe mentioned above. Each tank was provided with a feed cock, upon which, of course, the ball-cock maintained a practically constant head. Some of the feed cocks were of fine construction, and were provided with quadrants and pointers, so that the rate of flow might be adjusted more easily. All of the feed tanks were provided with filtering partitions of cloth, which materially prevented the clogging of these feed cocks. Regulation of the rate of coagulant addition was effected by noting the number of cubic centimeters which flowed from the cocks in a given time.

The coagulant solutions discharged into funnels, which, in turn, were connected to a 0.5-inch rubber hose, which, in turn, could be readily connected with any one of the lead pipes which terminated either in the perforated pipes in the coagulating troughs or at the bottoms of the 0.5-hour coagulating basins. During April a settling and filtering chamber was placed in the pipe line leading from the coagulant barrels to the feed tanks.

FILTERS.

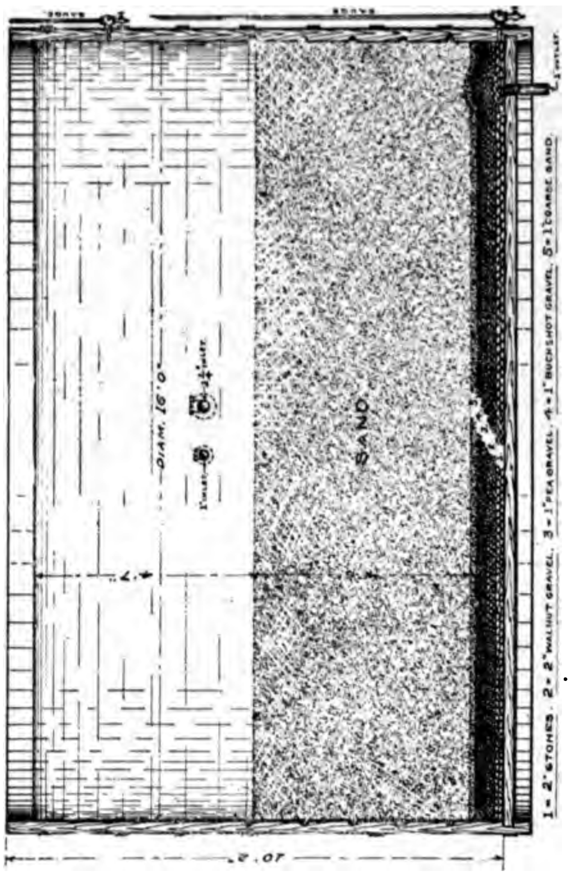
The general arrangement of the filters is best shown on the plates accompanying this chapter. They may be described as follows:

ENGLISH FILTER NO. 1.

Tank.—The filter tank was made of cypress. It was 16 feet in diameter and 10.2 feet deep. The sides and bottom were 2.25 inches

PLATE, NO. 7

SECTION OF ENGLISH FILTER No. 1.



thick and the staves were held in place by eight galvanized hoops of varying widths and thicknesses. Four circumferential grooves, each 0.625-inch wide and 0.625-inch deep were cut around the inner surface of the tank. They were 12 inches apart, the lowest groove being 14 inches above the bottom of the tank. These grooves were designed to guard against the more rapid percolation of water around the periphery of the filter, between the walls of the tank and the sand layer. As a further precaution, the walls of the tank were first coated with black asphaltum varnish and then sanded. The bottom of the tank was level and the sides were vertical.

Piping Connections.—There were two inlets for Filter No. 1—of 1-inch and 1.25-inch wrought-iron pipe, respectively. These pipes entered the filter tank at points 4 feet below the top of same. Both inlet pipes were provided with valves and terminated inside of the filter in elbows which were turned upward so as to avoid disturbances of the sand layer during the operation of the filter. A 1-inch pipe in the botton of the tank served as an outlet. This outlet pipe was fitted with a valve and was connected with a 1-inch Worthington water meter. Suitable 1-inch piping connections permitted the refilling of the filter, after scraping, with filtered water, from below, and also the by-passing of the basin effluent around the filter and through the meter during scraping.

Gauges.—Loss-of-head-gauges consisted of glass tubes attached to the filters. One of the tubes connected with the gravel layer and measured the pressure in the under-drains. The other connected with the water above the sand layer, and showed the pressure at the surface of the same. The difference in the height of these two water columns showed the loss of head.

Under-Drains.—The sand was supported upon a layer of graded washed gravel. Generally speaking, a layer of gravel will remain on top of a lower layer, provided it contains no particles less than one-third the size of the particles of the material upon which it rests. Working on this principle, the coarser material on the local market was sized into three grades, and the finer—that which is used for cement sidewalks—into two. The sizes of the sieves used for this purpose were determined from the inspection of the results of the mechanical analysis of the raw material. All gravel was washed before being put into the filters.

The following layers were put into the filters:

1. Stones ....2 inches thick.
2. Walnut Gravel...2 " "
3. Pea Gravel.........1 " "
4. Buckshot Gravel.1 " "
5. Coarse Sand.......1 " "

The coarser gravel came from Portugal as ballast. There is a
equally good gravel on the market from Prophet's Island, in the Mis
sissippi, near the mouth of the Red River.

The results of mechanical analyses of these gravels are given i
the next table.

TABLE XXIV.

Mechanical Analyses of Gravels.

Percentages by Weight Finer than Given Diameters.			
Stones Gravel Layer No. 1		Walnut Gravel Gravel Layer No. 2.	
Size in Millimeters	Percentage Finer	Size in Millimeters	Percentage Finer
40.0	100.	25.0	100.
31.7	89.	17.1	79.
28.2	82.	15.8	64.
27.2	76.	15.3	52.
26.6	70.	14.8	41.
25.9	65.	14.0	31.
24.7	60.	12.9	23.
23.5	52.	12.1	16.
22.5	45.	11.0	11.
22.1	40.	10.2	7.4
21.6	34.	9.5	4.1
21.1	27.	6.8	0.0
19.9	22.		
19.3	15.	Effective size ....10.8 m.i	
18.3	10.		
18.0	5.0	Uniformity co-efficient....... 1.43	
15.8	1.4		
12.1	0.22		
6.6	0.016		
Effective size......................19.3 m.m.			
Uniformity co-efficient........ 1.28			

Finer than (Millimeters)	Percentages by Weight: Pea Gravel Gravel Layer No. 3	Buckshot Gravel Gravel Layer No. 9	Coarse Sand Gravel Layer No
8.15	100.00	....	....
6.97	70.45	....	....
5.81	52.70	100.00	....
4.52	30.00	93.69	100.00
1.92	1.35	23.10	99.86
1.23	0.04	0.25	60.27
0.937	....	0.13	31.02
0.653	....	0.07	9.36
0.456	....	0.06	3.62
0.314	....	0.06	2.19
0.237	....	0.05	1.10
Effective size	3.35 m.m.	1.75 m.m.	0.66 m.
Uniformity co-efficient......	1.64	2.00	1.87

Sand Layer.—The original sand layer was 4.5 feet thick and w
composed of very fine sand of an effective size of 0.21 millimeters a
having a uniformity co-efficient of 1.57. This was an extreme thic

ness of sand layer, composed of the finest sand obtainable upon the market at the time of purchase. This construction was decided upon for the filter because experience in other places had shown that, other things being equal, thickest layers of finest sand gave the highest qualitative efficiency. It was desired to have this filter operate under the most favorable conditions. A table of sand analyses is given beyond.

Construction of Sand Layer.—The sand for the filter was shoveled upon a platform of planks which was suspended from the top of the filter, and which reached to within three feet of the bottom. The sand was first shoveled on this platform and thence on to the filter, each shovelful being spread as thrown. The sand for this filter was sieved through a 1 millimeter perforated metal sieve in order to remove balls of clay, leaves, sticks, etc. After the first scraping it was desired to put in new sand in order to increase the depth of the sand layer to 5 feet as originally intended. Accordingly this was done after the sand had been scraped as usual to the depth of 0.97 inch. This procedure was found to be impracticable, however, as clogging took place at the place of junction between the old and new sand layers, so, after another scraping, the second addition of sand was removed. There still remained 4.1 feet of sand in the filter. The sand layer had compacted about 10 per cent since first placed in the filter.

MODIFIED ENGLISH FILTER NO. 2.

The tank of this filter was 9.8 feet in diameter and 8.2 feet deep. It was first filled with 3.0 feet of Horn Island sand of 0.385 millimeters effective size, and of a uniformity coefficient of 1.48. After the eleventh period of operation, the Horn Island sand had decreased to a thickness of 2.1 feet, and, accordingly, 9 inches of sand were placed in the filter, first removing all the upper layer of dis.olored sand. The new sand had an effective size of 0.33 millimeters, and a uniformity coefficient of 1.42. With the above exceptions, the filter was constructed, fitted and under-drained similarly to Filter No. 1.

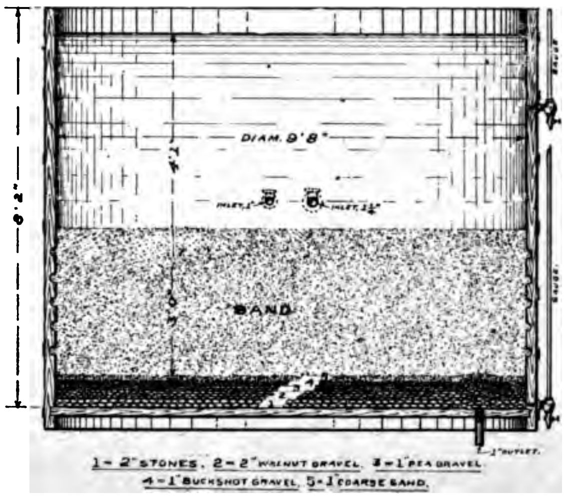
AMERICAN FILTER NO. 3.

This was a 4-foot gravity filter of the American type, constructed by, and purchased from, the New York Continental Jewell Filtration Company. This kind of filter is known to the trade as the Continental Filter. It departed in no essential particular from the usual designs of the American type of filter, except that air, instead of the more common mechanical agitator, was used to agitate the sand during washing.

In general, the filter consisted of a steel tank, at the bottom of which there were placed strainers for the collection of filtered water, and for the admission of water or air during washing. This tank contained a sand layer supported upon a layer of gravel. The various

PLATE, NO. 8

SECTION OF ENGLISH FILTER No 2.



S.H.

parts are described in order, first,—as purchased from the Filter Company, and then as rearranged by the Company in February, (Plate IX.)

Steel Tank.—The tank which held the sand layer was composed of two parts, an inner and an outer tank.

The inner tank was 4 feet in diameter and 5 feet 7 inches deep. Twelve inches above the bottom of the tank there was a partition which formed a support for the filtering layer. Into this partition the strainer cups were screwed, and the space between the false and true bottom acted as a filtered water chamber. This chamber held, approximately, 12.6 cubic feet, or about 4 minutes' normal flow of the filter. The main portion of the inner tank was occupied by the sand layer, which was 2.6 feet thick. The sand layer was supported upon a layer of fine uniform gravel, 4.5 inches thick. The upper 9 inches of this tank served as a water space above the sand layer.

The outer tank, the top of which projected 1 foot above the inner tank, was a ring of steel, 4 feet 4 inches in diameter and 3 feet high. This was slipped over the inner tank for two-thirds of its height, forming a circumferential trough, 2 inches wide and 2 feet deep. This trough received the wash-water as it flowed over the edge of the inner tank during washing, and also served to distribute the water applied to the filter during filtration.

Piping Connections.—All piping connections were 2.5 inches in diameter, with the exception of the waste pipe, which was 3 inches in diameter. The outlet and wash water supply pipes were joined just outside of the filter, and were connected to the filter just above the bottom and below the false bottom of the inner tank. The inlet pipe was connected to the filter at a point 2 feet below the top of the outer tank. The waste pipe was connected with the circumferential trough near its bottom. A by-pass connected the inlet and outlet pipes so that water could be wasted through the controller at normal rates. thus permitting the stopping of the filter without interrupting the flow of the water through the basins.

Strainer System. — Perforated brass cylinders, 50 in number, formed the strainer system of this filter. They were screwed into the false bottom, and were spaced about 6 inches from center to center. These strainer cups were made of brass tubes 1 inch in diameter, closed at the top. The tops and sides were drilled with thirty 0.06-inch holes, and projected above the false bottom for about 1.0 inch. The total area of holes in each strainer was .092 square inches, or 46 square inches for the whole strainer system. Naturally, the holes in these strainers were too coarse to retain the sand used in the filter, and, consequently, a 4.5-inch layer of fine uniform gravel was placed in the filter to support the sand. The mechanical analysis of this gravel is given below :

TABLE XXV.

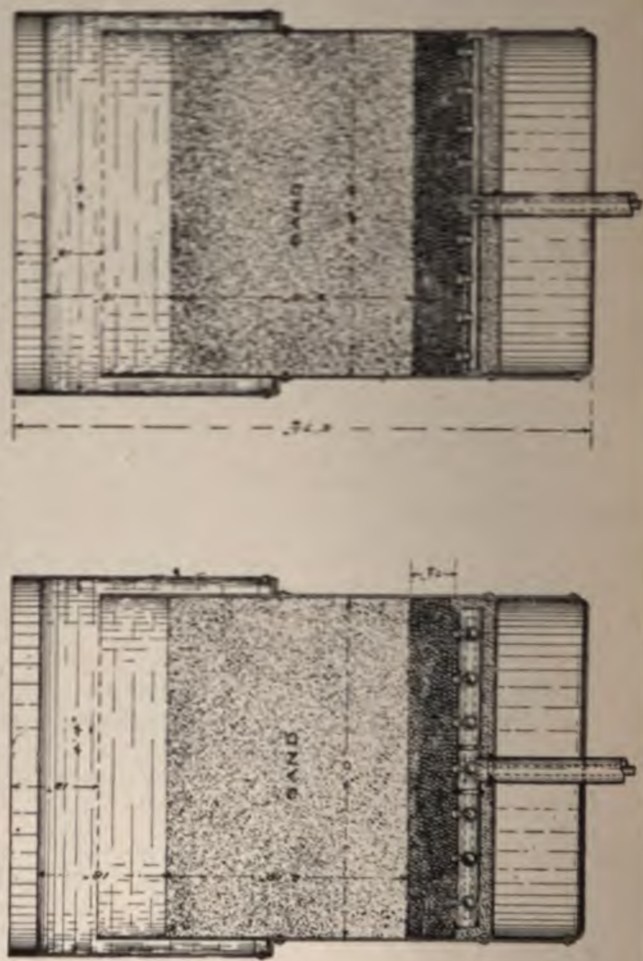
Mechanical Analysis of Filter No. 3 Gravel.

Finer than 4.52 m.m.	100.00 per cent.
Finer than 1.92 m.m.	0.38 per cent.
Finer than 1.23 m.m.	0.07 per cent.

The average mean diameter of the particles equaled 3.1 m.m.

SECTIONS OF AMERICAN FILTER No. 3.

PLATE, No. 5



Modifications of the Strainer System.—In February the strainers were removed from the false bottoms and were screwed into a system of effluent pipes which rested upon the false bottom itself. The main pipe of this system followed the diameter of the filter, and was made of 3-inch wrought-iron pipe. Into this main pipe, 1.5-inch lateral pipes were screwed. The holes in the false bottom were pluged, the whole system was imbedded in Portland cement mortar, and 6 instead of 4.5, inches of gravel were placed above it. This system of piping found its outlet through a vertical 3-inch pipe which passed through the bottoms of the filter at its center. This change was made in order to effect a better distribution of air—used in washing—than had been possible with the filter as earlier arranged.

Tests were made of the frictional losses occasioned by the strainer cups, gravel layer and effluent piping system, with the following results:

LOSSES OF HEAD IN FILTER NO. 3 WHEN OPERATING AT A RATE OF 25 GALLONS PER MINUTE, OR 125,000,000 GALLONS PER ACRE PER DAY.

FILTER NO. 3.

Old Strainer System.

Velocity head of effluent piping	0.04 foot.
Loss of head due to effluent piping	0.55 "
" " " " " and strainers	0.60 "
" " " " " strainers and gravel	0.70 "

New Strainer System.

Loss of head due to effluent piping	0.55 feet.
" " " " " and strainers	0.60 "
" " " " " strainers and gravel	0.76 "

Since the total friction of this filter, directly after washing, varied from 1.6 feet to 5.9 feet, at the regular rate of filtration, depending upon the size of the sand and the thickness of the sand layer used, it will be readily seen that the sand layer was the most important factor in causing losses of head in this filter.

Agitating Device.—An agitating device was provided for the purpose of stirring the sand layer during washing. This device consisted of a Knowles air pump and a system of air distribution. The air pump was 5 inches by 10 inches by 7 inches in size. From this blower a 0.75-inch pipe led to the space below the false bottom. A deflector was attached to the end of this pipe. A branch of this pipe

was connected with an escape pipe so that the pump could be run continuously and the air allowed to escape or to be discharged into the filter at will.

The distribution system was quite simple. Each strainer tube projected below the false bottom for about 1.5 inches A 0.06-inch hole was bored in the side of each of these tubes at points just below the false bottom, thus forming traps. Air was pumped into the space between the true and false bottoms. The air was then supposed to pass through the small holes in each strainer and to find its way uniformly up through the sand layer. A deflector was fastened to the end of the 0.75-inch air supply pipe with the intention of spreading the air in a thin stratum which would not be thick enough, at any one place, to allow the air to pass up through the bottoms of the strainers instead of through the small air holes. The reciprocating air-pump, however, produced such an irregular flow of air that the latter was spasmodically admitted to the under-drains and sand layer through the bottoms of the strainer tubes and caused the gravel to be displaced, as is shown in Chapter VI. Consequently, the air distribution system was modified by a representative of the Filter Company, as follows:

Modifications of the Air Distribution System.—The modifications of the strainer system have been noted above. The air distribution system was modified so as to make the air escape just beneath each strainer by means of a system of pipes within the effluent pipe system. This pipe system consisted of a main 0.75-inch pipe, within the 3-inch effluent pipe, and of 0.37-inch lateral pipes, closed at the ends, within the 1.5-inch lateral effluent pipes. A .0625-inch hole was drilled in this pipe system directly beneath each strainer. This arrangement practically overcame the ill effects of the irregular discharge of the air pump.

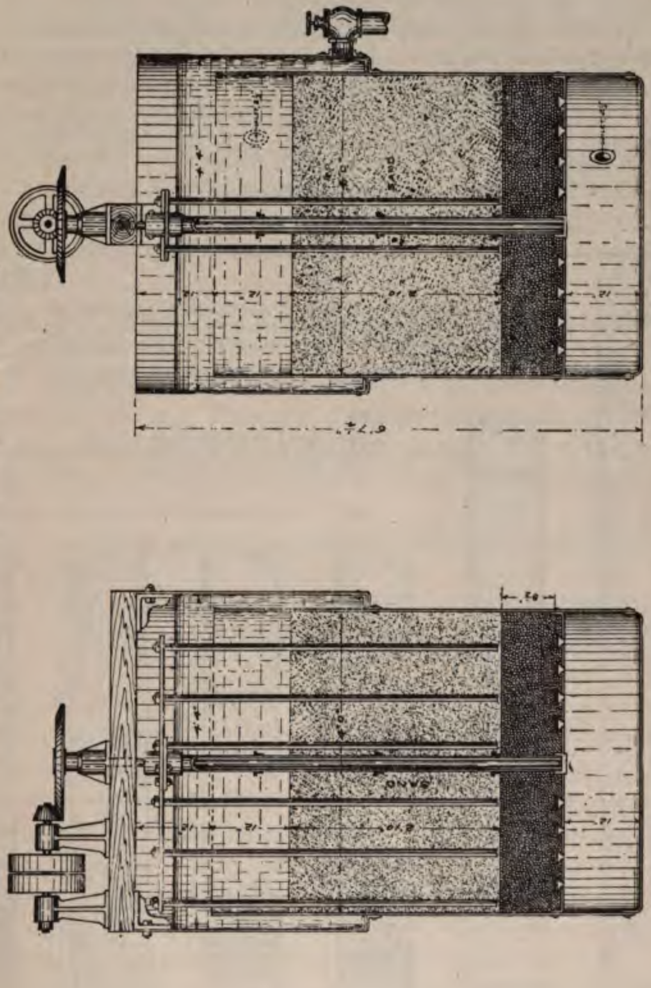
AMERICAN FILTER NO. 4.

This was a 4-foot gravity filter of the American type, having strainers screwed into a false bottom; and it differed from the original Filter No. 3 in nothing except strainers and agitating device. Therefore, the description of the original Filter No. 3 (before February alterations) will suffice for Filter No. 4, except in the following particulars:

Strainer System.—The strainer system consisted of 50 brass strainer cups screwed into the false bottom of the filter. These strainers were of the usual Jewell inverted cone-shaped pattern. The face of the cup was covered with a punched bronze sheet, the sheet being secured to the cup by a metal ring which was riveted to the cup flange. These strainers are too well known to need further description. The loss of head due to this strainer system and the connected effluent piping at the regular rate of flow, was 0.70 foot.

PLATE, NO. 10.

SECTIONS OF AMERICAN FILTER No 4.

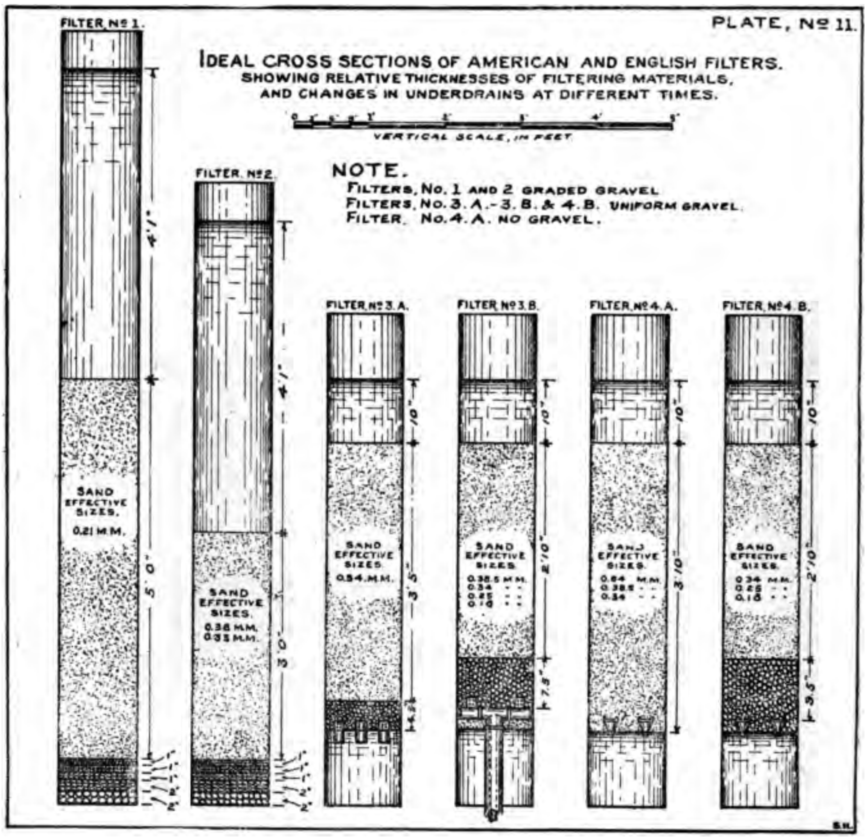


S.H.

Agitator.—The agitator consisted, briefly, of two horizontal rake arms, one of which carried 3, and the other 4, rake teeth made of 0.875-inch square iron, and extending down into the sand layer to within 1.5 inches of the top of the strainers. On April 20th, when gravel was put into this filter to a depth of 9.5 inches above the top of the strainers, the rake teeth were cut off so as to just touch the top of the gravel layer. This agitator was attached to a vertical shaft, which could be revolved in one direction by means of a 2-horse power vertical engine connected with the agitator by belting, shafting and bevel gearing.

Gravel to a depth of 9.5 inches above the top of the strainers, and of the same size as used in Filter No. 3, was put into the filter on April 20th. This was done that the same thickness of sand, and the same distance between the top of the sand and the top of the wash water overflow partition might exist in each filter.

A sketch showing the main features of this filter may be seen on Plate X.



SANDS USED IN FOUR FILTERS.

As it was important to learn which of the available local sands was best suited as a filtering medium in the various filters, especially in Filters Nos. 3 and 4, the sands were changed quite frequently,

Again, it was desired to have Filters No. 3 and No. 4 operate with the same thicknesses of sand layer, and therefore, because the depth of Filter No. 3 was less than that of Filter No. 4, a correspondingly thicker layer of gravel was put into Filter No. 4.

The following diagram, Plate XI, illustrates the relative thicknesses of sand and gravel layers in the four filters at different times:

Figure No. 1 shows a representative cross-section of Filter No. 1.

Figure No. 2 shows a representative cross-section of Filter No. 2.

Figure No. 3 shows a representative cross-section of Filter No. 3, before changes were made in the strainer and air distribution systems.

Figure No. 4 shows the same as Figure No. 3, but after the changes were made in the strainer and air distribution systems.

Figures No. 5 and No. 6 show representative cross-sections of Filter No. 4 before and after the placing of the gravel layer in the filter.

What immediately follows shows the mechanical analyses, albuminoid ammonia contents, and periods of use of the various sands used in the four filters:

Filter No. 1.—This filter operated with only one kind of sand, known to the trade as Lake Shore Sand. This sand came from the bed of the Tchefuncta River; it was pumped up from beneath the water by a suction dredge. This sand contained 1600 parts of clay per million. It was passed through a 1-millimeter sieve before being put into the filter. This sieving effected the removal of a large part of the clay, also shells, pieces of leaves, bark, etc.

Filter No. 2.—Two sands were used in this filter, both of which were washed before use.

Sand No. 1 was said to have come from Horn Island in the Mississippi Sound. It was clean, beautiful, white sand with rounded grains, which was free from clay, but which contained a small amount of vegetable detritus, most of which was removed by washing.

Sand No. 2 was from a bar at the mouth of one of the rivers flowing into the north side of Lake Pontchartrain. It was similar to Sand No. 1, excepting that it had a very slight reddish color, due to a small amount of iron. It was called gravel sand. This was the sand which was used on July 10th to restore the sand layer to its original thickness. The sand which was replaced, however, consisted partly of Sand No. 1. which had been removed from the filter by scraping and which was washed and replaced on top of Sand No. 2.

Filter No. 3.—Sand No. 1 was a sifted beach sand from Norfolk, Va. It was a very clean sand with rounded grains. This sand was in use from December 15 to February 26.

Sand No. 2 was Horn Island sand, the same as was in Filter No. 2. This sand was in use from February 27 to April 10.

Sand No. 3 was called Henderson Point sand, and was said to have come from Henderson Point, which reaches out into Mississippi Sound on one side of Bay St. Louis. This sand was in use from May 3 until June 14.

Sand No. 4 was Lake Shore sand, the same as that used in Filter No. 1. This sand contained clay and vegetable matter, most, but not all of which was removed by sieving, and washing in the filter. This sand was in use from June 15 until August 8.

Sand No. 5. This was a mixed sand from Prophet's Island, which is situated in the Mississippi River near the mouth of Red River. This was a very fine sand, containing 2,500 parts of clay per million, and a small amount of coal. This sand was quite free from organic matter. The size of the sand furnished by the dealer did not correspond with the size of the sand in the sample taken from the pile. Accordingly, much finer sand was put into the filter than was intended. This sand was in use from August 9 until the close of the investigations.

Filter No. 4—The sands used in Filter No. 4 were identical with those used in Filter No. 3. However, the periods of use varied slightly, as follows:

Sand No. 1 was in use from December 15 until February 24.
Sand No. 2 from February 28 until April 5.
Sand No. 3 from April 8 until June 26.
Sand No. 4 from June 27 until August 6.
Sand No. 5 from August 7 until the close of the investigations.

MINERALOGICAL COMPOSITION OF THE SANDS.

With the exception of the sands from Norfolk and from Prophet's Island, all the sands used were composed of almost chemically pure quartzite.

MAXIMUM RATES OF SANDS IN FILTERS NOS. 3 AND 4.

The usual mechanical analysis of a sample of sand determines a value which is known as the effective size. This means that 10 per cent by weight of the sand is finer than the given size in millimeters. The mechanical analysis also determines another value which is called the uniformity co-efficient, and which varies inversely with the uniformity of the sand. The velocity of the water passing through sand in a filter under conditions of practice has been expressed by the formula

$$V = cd^2 \frac{h}{l} \left(\frac{t^\circ \text{ Fahr.} + 10^\circ}{60}\right)^*$$

Where V equals the velocity in vertical meters per day, or approximately in million gallons per acre per day.

d equals the effective size of the sand grains in millimeters;

h equals the loss of head;

* Hazen: Report Massachusetts State Board of Health, 1892, p. 553.
Hazen: Filtration of Public Water Supplies, 3d edition, p. 22, New York, 1900.
Clark: Report Massachusetts State Board of Health, 1894, p. 703.

l equals the thickness of the sand layer;
t equals the temperature (Fahrenheit);
c equals the approximately constant factor.

The value of c is generally taken as 1,000. Clark, however, has shown that the value of c varies with the compactness of the sand layer, the chemical composition of the sand, the presence of loam and fine particles, the age of the sand layer and the uniformity co-efficient. All the above factors affect the value of c—that is, affect the relation between the effective size of the sand grains and the friction of the sand layer—to a great extent, so that it varies in practice from 500 to more than 1,000. It might also be noted that in the case of American filters, which, of course, are washed by reverse currents of water, there is a possibility that this value of c might be affected under certain conditions by the stratification of the sand layer, according to the hydraulic values of the sand grains.

Sands are sometimes sized by determining their maximum rates; that is, the rate at which water free of sediment at a temperature of 50 degrees F. will flow through sands in filters when the loss of head equals the thickness of the sand layer, or, in the above formula, when $\frac{h}{l}$ equals 1.

The following table shows the differences between these maximum rates, determined experimentally at this station, when the materials were new, and those calculated from the formula. These differences are, perhaps, explained by the differences in the uniformity of the sands, in the percentages of fine particles, and also in the shape of the particles, as mentioned above.

TABLE XXVI.

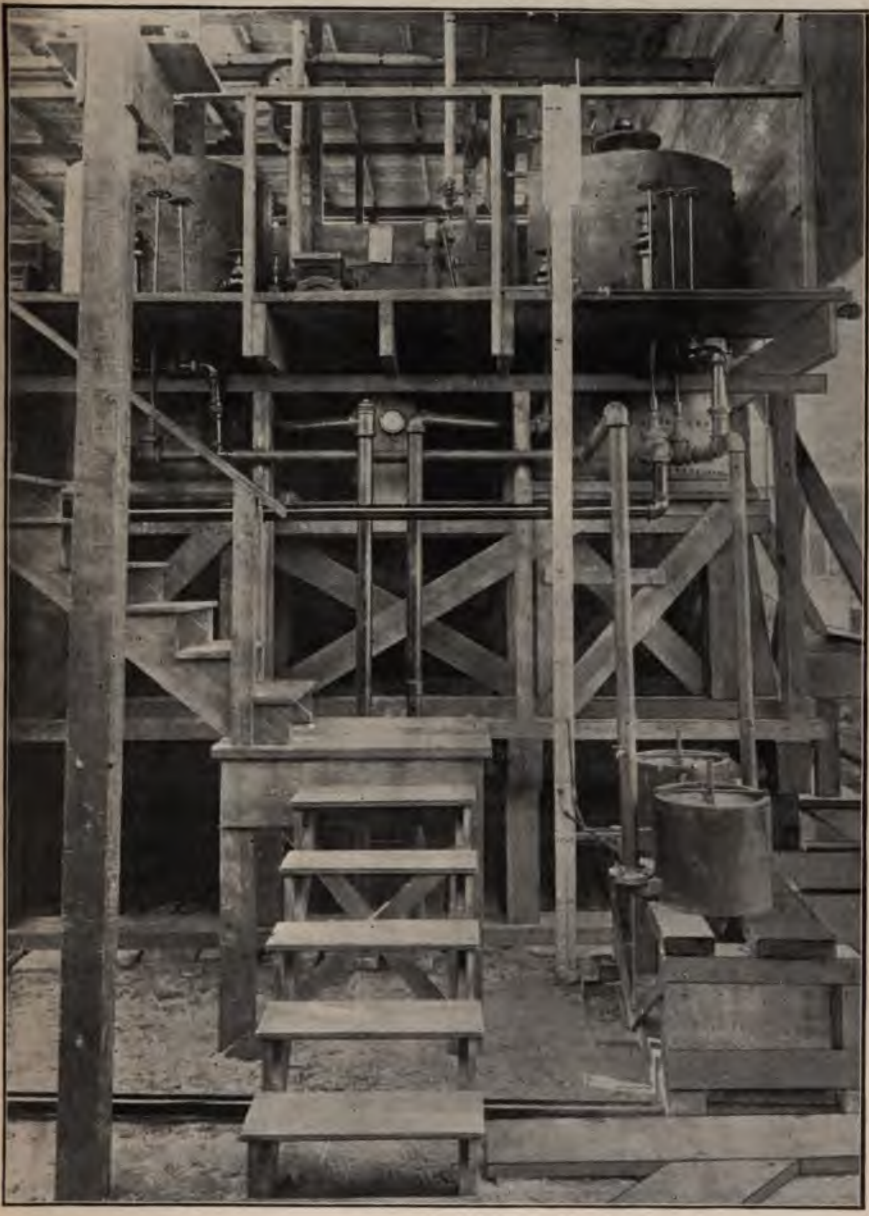
Table Showing the Differences Between the Calculated and Experimentally Determined Maximum Rates of Filtration for Four of the Sands Used in the American Filter No. 3.

Name of Sand.	Effective Size.	Uniformity Co-efficient.	Per Cent Finer than 0.237 m.m.	t° (F)	Maximum Rate in Million Gallons per Acre per 24 Hours. By Formula C = 1000.	By Experiment.
Norfolk................	0.54	1.30	0.02	50	292	176
Horn Island...........	0.385	1.48	0.08	45	148	131
Lake Shore............	0.25	1.80	5.96	46	125	123
Prophet's Island.....	0.18	1.83	23.80	80	32.4	65.7

The thickness of the layer of Norfolk sand was 41 inches; of the other three sands, 34 inches.

TABLE NO. XXVII.— *Showing Results of Sand Analyses.*

Sand Number.	Uniformity Co-efficient.	Effective Size.	PERCENTAGE BY WEIGHT FINER THAN m. m.										Albuminoid Ammonia	Began Using.	Ceased Using.
			4.52	1.92	1.23	0.937	0.653	0.456	0.314	0.237	0.190	0.134		1900-1901	1901
							Filter No. 1.								
1	1.57	0.21	100	100	100	99.8	98.3	84.7	55.2	15.9	7.65	2.73	5.75	Dec. 21	Aug. 1
							Filter No. 2.								
1	1.52	0.38	100	100	99.7	98.2	75.1	22.8	4.40	0.12	....	....	5.20	Dec. 15	Aug. 17
2	1.42	0.33	100	100	99.8	99.3	94.8	51.6	8.01	0.61	....	....	4.17	July 10	Aug. 17
							Filter No. 3.								
1	1.30	0.54	100	100	99.9	99.3	42.5	3.03	0.51	0.02	....	....	3.95	Dec. 15	Feb. 26
2	1.48	0.385	100	100	99.8	98.5	81.2	25.8	4.48	0.08	....	....	5.30	Feb. 27	Apr. 10
3	1.41	0.34	100	100	99.8	99.4	90.6	34.1	4.46	0.06	....	....	4.30	May 3	June 14
4	1.80	0.25	100	99.4	98.4	96.9	89.1	60.6	28.5	5.96	2.74	....	8.50	June 15	Aug. 8
5	1.83	0.18	100	100	99.7	99.2	96.9	80.3	54.3	23.8	13.0	3.08	7.90	Aug. 9	Aug. 17
							Filter No. 4.								
1	1.30	0.54	100	100	99.9	99.3	42.5	3.03	0.51	0.02	....	....	3.95	Dec. 15	Feb. 24
2	1.48	0.385	100	100	99.8	98.5	81.2	25.8	4.48	0.08	....	....	5.30	Feb. 28	Apr. 5
3	1.41	0.34	100	100	99.8	99.4	90.6	34.1	4.46	0.06	....	....	4.30	Apr. 8	June 26
4	1.80	0.25	100	99.4	98.4	96.9	89.1	60.6	28.5	[illegible]	2.74	....	8.50	June 27	Aug. 6
5	1.83	0.18	100	100	99.7	[illegible]	[illegible]	[illegible]	54.3	[illegible]	[illegible]	[illegible]	7.90	Aug. 7	Aug. 17



GENERAL VIEW OF AMERICAN FILTERS AND CONTROLLERS.

CONTROLLERS FOR FILTERS NO. 3 AND NO. 4.

Automatic controllers, of the form designed by E. B. Weston, M. Am. Soc. C. E., were used to keep the flow of water through these filters constant. The general form of this controller is shown on Plates IV and V and in the photograph of Filters No. 3 and No. 4 (Plate XII). It has also been described several times by the engineering press.

The controller is simply a nicely constructed chamber in which there is an annular orifice, over which a constant head of water is maintained by means of a float which operates the butterfly inlet valves. The orifice can be easily varied in size. The head above the orifice could also be slightly varied in order to adjust the discharge of the controller accurately. These controllers worked very well and kept the flow of water through the filters to within about 2 per cent of the desired rate.

CONTROLLER BOXES AND CLEAR WATER TANK.

The controllers discharged into two controller boxes (Plates IV and V), which were provided with baffles and standard orifices, for the purpose of making check measurements of the discharge of the controllers.

The water from the controller box of Filter No. 4 flowed into a clear water tank. This tank was constructed of brick masonry, plastered on the inside with cement. It was 6.5 feet long, 3.6 feet wide, and 3.0 feet deep. It had a capacity of about 500 gallons. A 2.5-inch suction pipe led from the clear water tank to a 4-inch by 3.75-inch by 4-inch Worthington pump, which latter discharged into the tower tank shown on Plates III and IV.

TOWER TANK.

A trestle 33 feet high supported a cypress tower tank. This tank was about 10 feet in diameter and 5.5 feet deep and held about 3,000 gallons of water when full. From the bottom of this tank a 3-inch stand pipe depended, the lower end connecting with the tank pump. This pipe was provided with connections, as follows:

a.—A pair of 1-inch pipes leading to the coagulant barrels.

b.—A 3-inch connection leading through a 2.5-inch meter to the wash-water inlets of Filters No. 3 and No. 4, and also to the outlet pipes of Filters No. 1 and No. 2.

c.—A 2.5-inch connection for the fire hose.

d.—A 1-inch pipe which led to the discharge of the main pump, by means of which—and by a by-pass around the pump itself—the suction intake pipe could be filled with water between the foot valve and the pump.

e.—A 1.5-inch pipe leading to the boilers and laboratory.

There was a float in the tank which was connected with a valve in the steam pipe of the tank pump and which shut off the steam supply whenever the tank became full.

The top of the tank was 30 feet above the bottoms of Filters No. 3 and No. 4.

BOILER HOUSE.

The boiler house was a rough wooden building, 25 feet long by 15 feet wide. It served to protect the boilers, gas machine, tools, oil, supplies, etc.

The two boilers were of the ordinary vertical tubular type, each 6 feet high by 3 feet in diameter. A small duplex pump acted as a boiler feeder. The general plan of the boiler house is shown on Plate IV.

LABORATORY.

A rough, but well-lighted and adequately equipped wooden building was erected for use as an office and laboratory. It was supplied with steam and gasoline gas. The water supply was taken from the tower tank. The general plan of the laboratory is shown on Plates IV and V.

CHAPTER III.

Manner of Operation of the Plain Subsiding Basins, and the Efficiency of Plain Subsidence for Various Periods in the Clarification and Purification of the River Water.

GENERAL PLAN OF OPERATION.

There were 4 continuous subsiding basins in operation, known as Nos. 1, 2, 3 and 4, respectively. At the beginning of the investigations the period of subsidence in these basins was nominally 72, 48, 48 and 24 hours, respectively; but these periods were changed during April, as is described below.

Continuous Plan.—All the basins were operated on the continuous plan, the water entering at one end of each basin at a point about 2 feet above the bottom, and issuing at the opposite end near the surface.

Cleaning.—All of the basins were cleaned twice; once during April, and again during August, subsequent to the final shutting down of the plant.

LATER MODIFICATIONS IN GENERAL PLAN OF OPERATION.

The general plan of operation was practically unchanged during these investigations. During April, however, baffles and partitions were put into Basins Nos. 1, 2 and 4, as is described in Chapter II, in order that data might be obtained regarding the efficiencies of shorter periods of subsidence, and in order to reduce the period of subsidence which experience up to this time had indicated to be too long. Accordingly, the nominal period of subsidence of Basin No. 3 was reduced from 48 to 12, and that of Basin No. 4 from 24 to 12 hours, respectively.

During the earlier part of the work there were several delays incident to the tightening of the wooden basins.

The following notes, which were presented in chronological order, will give a more detailed and comprehensive view of the operation:

1900.

December 6.—Began filling the basins with water.

December 15.—All basins except No. 1 put into operation.

December 17.—All basins in operation; Basin No. 1 operating at half-rate.

1901.

January 8.—Partially drained Basins No. 1 and No. 2 to put in an auxiliary pipe connecting basins and filters.

Increased the flow through Basin No. 1 to the full rate.

February 2.—Stopped Basin No. 3 to make alterations in pipe system of Filter No. 3.

February 9.—Basin No. 3 again put into normal operation.

Shut down Basin No. 3 on April 11th, and No. 2 on April 12th to remove sediment and put in baffles.

April 17.—Entire plant was shut down because of a severe rain which flooded the steam pipe connecting the boilers with main pump and effectually prevented the pump from running because of condensed steam in the pipe. This condition lasted until April 18th.

Shut down Basin No. 1 on April 18th, and Basin No. 4 on April 23d to remove sediment and to put in partition baffles.

After these modifications the basins were again put into operation as follows:

Basin No. 1 on April 22d.

Basin No. 2 on April 23d.

Basin No. 3 on April 28th.

Basin No. 4 on May 17th.

May 20.—Partially drained No. 4 to repair baffles.

June 5.—Basin No. 2 was put out of service. After this date the unsettled river water was supplied directly to Coagulating Basin No. 2.

June 25 to August 10.—During this period the river was so low that the main pump had to be stopped several times for slight repairs which were rendered necessary by the excessive suction lift, which at times amounted to 28 feet, including friction.

The entire plant was also shut down for a few hours because of the flooding of the steam pipe during a severe rain storm.

As a general rule, the operation of the plant was as continuous as could be desired, and delays and accidents were few.

DESCRIPTION OF TABLES SHOWING RESULTS OF OPERATION OF SUBSIDING BASINS.

In the following tables are presented all the leading results of operation of the subsiding basins, arranged by dates, and also the total averages for the entire investigations. The leading data presented may be briefly explained as follows:

Collection of Samples.—Three samples of river water, and two or three samples of subsiding basin effluents were collected each day for the determination of silica turbidity. The suspended matter was determined gravimetrically on daily averages of samples from each of the above sources. As the work progressed, however, the frequency of the gravimetric determinations of suspended matter was diminished. After the baffles and overflow partitions had been put into the basins, the number of silica turbidity samples was increased so as to include the turbidity samples which were taken at the intermediate points.

In general, bacterial samples were taken corresponding to the turbidity samples. The regular hours of sampling were 8 o'clock in the morning, 4 o'clock in the afternoon, and at midnight, respectively. Special samples were taken from the basins for microscopical examination, and for the determination of the degree of stratification of the suspended matter. The temperature of the water in the basins at different depths was frequently determined.

Dates.—The dates given are those on which the sample was taken from the basin. They were compared with river samples which were taken previously, and which might be said to fairly represent the basin sample before being subjected to subsidence.

Stage of River.—The stage of the river at 8 A. M. on the date corresponding to the river sample taken is recorded.

Period of Subsidence.—The period of subsidence in hours was considered equal to the total capacity of the basin in gallons, divided by the rate of flow in gallons per hour.

Silica Turbidity.—The silica turbidity of the river water and that of the basin samples represent the turbidity of the same water before and after subsidence as nearly as working errors will permit.

Suspended Matter.—The results recorded are those of average daily samples, and correspond to the average of the silica turbidity results for the same date.

Bacteria.—The numbers of bacteria per cubic centimeter in the river water and in the subsided water are given. The recorded results are the averages of two or three determinations.

Efficiencies.—The efficiency of removal by plain subsidence of silica turbidity, suspended matter and bacteria, respectively, are recorded. These efficiencies are expressed in the usual manner as the percentages of difference between the amounts contained in the river water and in the same water after subsidence for different periods.

Methods of Analysis.—These are the same as outlined for the river water (page 25). In this connection, it may be said that the diaphanometer proved to be a most useful instrument for quickly and correctly recording the results of plain subsidence.

Leakages.—During the investigation, there was more or less leakage of the basins. This occurred chiefly at the beginning when water was first put into the tanks, and toward the end of the investigation when the sides of the basins had become more or less watersoaked and pervious. Leakage in these basins probably did not affect the accuracy of the work, since its amount was well within the limits of accuracy of the methods.

TABULATED LIST OF TABLES.

Showing the Operation and Efficiencies of the Various Subsiding Basins After Various Periods of Plain Subsidence.

Table No.	Subsiding Basin No.	Period of Subsidence.
XXVIII.	1.	24 hours.
XXIX.	1.	48 "
XXX.	1.	72 "
XXXI.	2.	6 "
XXXII.	2.	48 "
XXXIII.	3.	12 "
XXXIV.	3.	48 "
XXXV.	4.	12 "
XXXVI.	4.	24 "

TABLE No. XXVIII.

Showing the Operation and Efficiencies of Subsiding Basin No. 1, Using 24 Hours of Plain Subsidence.

Date, 1901.		Stage of River.	Silica Turbidity. River	Silica Turbidity. Subsided Water.	Silica Turbidity. % of Removal.	Date, 1901.		Stage of River.	Silica Turbidity. River.	Silica Turbidity. Subsided Water.	Silica Turbidity. % of Removal.
April	22.	11.2	550	350	36	June	21.	7.2	350	160	54
"	23.	11.4	525	300	43	"	22.	7.1	400	190	53
"	26.	11.7	625	350	44	"	23.	7.1	400	170	58
"	27.	11.8	650	250	62	"	24.	6.9	375	190	49
"	28.	12.0	675	220	67	"	25.	6.8	400	180	55
"	29.	12.2	700	120	83	"	26.	6.8	400	200	50
"	30.	12.1	775	130	83	"	27.	6.3	450	160	65
May	1.	12.2	725	240	66	"	28.	5.9	475	140	70
"	2.	12.3	725	170	77	"	29.	5.5	550	230	58
"	3.	12.3	700	350	50	July	1.	5.0	450	200	55
"	4.	12.5	700	450	36	"	2.	4.7	450	150	67
"	5.	12.4	650	425	35	"	3.	4.4	500	230	54
"	6.	12.6	600	375	38	"	4.	4.0	550	200	63
"	7.	12.4	550	375	32	"	5.	4.1	450	210	53
"	8.	12.6	575	350	39	"	6.	4.3	450	220	51
"	11.	12.4	500	280	44	"	7.	4.7	500	270	46
"	12.	12.5	525	260	50	"	8.	5.0	575	270	53
"	13.	12.6	500	300	40	"	9.	5.6	550	240	56
"	14.	12.4	475	350	26	"	10.	5.8	650	280	65
"	15.	12.7	400	280	30	"	11.	6.0	675	250	63
"	16.	12.7	400	260	35	"	12.	6.1	725	200	72
"	17.	12.6	400	250	37	"	14.	5.7	725	210	71
"	18.	12.6	375	240	36	"	15.	5.4	725	220	70
"	19.	12.6	350	190	46	"	16.	5.0	700	250	64
"	25.	11.3	260	150	42	"	17.	4.5	700	220	68
"	26.	10.8	250	125	50	"	18.	4.0	775	130	83
"	27.	10.3	270	150	44	"	28.	3.0	350	170	51
"	28.	9.8	260	140	46	"	29.	2.8	250	140	44
"	29.	9.1	270	170	37	"	30.	2.7	260	120	54
"	30.	8.4	250	170	32	"	31.	2.4	220	120	45
"	31.	8.0	300	160	47	Aug.	1.	2.2	190	110	45
June	3.	7.1	525	180	66	"	2.	2.0	160	120	25
"	4.	6.9	425	180	58	"	3.	2.0	160	120	25
"	5.	6.8	600	180	70	"	4.	1.9	160	120	25
"	6.	7.1	625	170	73	"	5.	1.9	160	110	31
"	7.	7.0	550	180	67	"	6.	2.1	130	100	23
"	8.	7.1	525	170	71	"	7.	2.2	150	100	33
"	9.	7.2	500	180	64	"	8.	1.9	130	90	31
"	10.	7.6	500	170	66	"	9.	1.8	120	90	25
"	11.	7.8	425	170	53	"	10.	1.9	120	90	25
"	12.	8.1	500	110	78	"	11.	1.7	110	85	23
"	13.	8.4	450	190	58	"	12.	1.6	130	90	31
"	14.	8.7	400	210	48	"	13.	1.6	110	85	23
"	15.	8.7	450	200	55	"	14.	1.7	95	80	5
"	16.	8.6	475	190	59	"	15.	3.2	90	100	......
"	17.	8.2	450	190	58	"	16.	5.4	150	100	33
"	18.	7.8	450	190	58	"	17.	2.0	140	100	29
"	20.	7.5	350	170	52	......	......	....	....	....	....

NOTE—Stage of River corresponds to River Turbidities.
Date corresponds to Subsided Water Turbidities.
Silica Turbidity results given in Parts per Million.

TABLE No. XXIX.

Showing the Operation and Efficiencies of Subsiding Basin No. 1, Using 48 Hours of Plain Subsidence

Date, 1901.	Stage of River.	Silica Turbidity.			Date, 1901.	Stage of River.	Silica Turbidity.		
		River.	Subsided Water.	% of Removal.			River.	Subsided Water.	% of Removal.
April 22.	11.2	600	375	37	June 21.	7.5	350	140	60
" 23.	11.2	550	220	60	" 22.	7.2	350	140	60
" 26.	11.6	575	150	74	" 23.	7.1	400	140	65
" 27.	11.7	625	140	77	" 24.	7.1	400	150	62
" 28.	11.8	650	170	74	" 25.	6.9	375	160	57
" 29.	12.0	675	110	84	" 26.	6.8	400	150	62
" 30.	12 2	700	140	80	" 27.	6.8	400	160	60
May 1.	12.1	775	325	58	" 28.	6.3	450	120	73
" 2.	12.2	725	180	75	" 29.	5.9	475	130	73
" 3.	12.3	725	280	61	July 1.	5.2	475	120	75
" 4.	12.3	700	350	50	" 2.	5.0	450	110	75
" 5.	12.5	700	350	50	" 3.	4.7	450	120	73
" 6.	12.4	650	350	46	" 4.	4.4	500	190	62
" 7.	12.6	600	300	50	" 5.	4.0	550	190	72
" 8.	12.4	550	290	47	" 6.	4.1	450	200	56
" 11.	12.6	525	290	45	" 7.	4.3	450	190	58
" 12.	12.4	500	220	56	" 8.	4.7	500	180	64
" 13.	12.5	525	230	51	" 9.	5.0	575	180	69
" 14.	12.6	500	350	30	" 10.	5.6	550	180	67
" 15.	12.4	475	270	43	" 11.	5.8	650	180	72
" 16.	12.7	400	230	42	" 12.	6.0	675	150	78
" 17.	12.7	400	210	48	" 14.	5.8	700	120	83
" 18.	12.6	400	230	42	" 15.	5.7	725	190	74
" 19.	12.6	375	230	39	" 16.	5.4	725	160	78
" 25.	11.6	260	85	71	" 17.	5.0	700	160	77
" 26.	11.3	260	90	65	" 18.	4.5	700	170	75
" 27.	10.8	250	110	56	" 28.	3.0	400	160	60
" 28.	10.3	270	110	59	" 29.	3.0	350	130	63
" 29.	9.8	260	150	42	" 30.	2.8	250	110	56
" 30.	9.1	270	150	46	" 31.	2.7	260	90	65
" 31.	8.4	250	120	52	Aug. 1.	2.4	220	90	59
June 3.	7.3	375	110	71	" 2.	2.2	190	110	42
" 4.	7.1	525	110	79	" 3.	2.0	160	110	31
" 5.	6.9	425	120	72	" 4.	2.0	160	110	31
" 6.	6.8	600	120	80	" 5.	1.9	160	85	47
" 7.	7.1	625	120	81	" 6.	1.9	160	85	47
" 8.	7.0	550	120	78	" 7.	2.1	130	90	31
" 9.	7.1	525	120	77	" 8.	2.2	150	75	50
" 10.	7.2	500	120	76	" 9.	1.9	130	70	46
" 11.	7.6	500	120	76	" 10.	1.8	120	65	46
" 12.	7.8	425	75	82	" 11.	1.9	120	70	42
" 13.	8.1	500	120	76	" 12.	1.7	110	65	41
" 14.	8.4	450	150	67	" 13.	1.6	130	70	46
" 15.	8.7	400	150	62	" 14.	1.6	110	75	32
" 16.	8.7	450	150	67	" 15.	1.7	95	95	...
" 17.	8.6	475	170	64	" 16.	3.2	90	90	...
" 18.	8.2	450	170	62	" 17.	5.4	150	80	47
" 20.	7.6	400	130	67	....	....	....	....	...

Note—Stage of River corresponds to River Turbidities.
Date corresponds to Subsided Water Turbidities.
Silica Turbidity results given in Parts per Millon.

TABLE No. XXX.

Showing the Operation and Efficiencies of Subsiding Basin No. 1. Using 72 Hours of Plain Subsidence.

Date. 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Subsided Water.	River.	Subsided Water.	River.	Subsided Water.	Silica Turbidity.	Suspended Matter.	Bacteria.
Jan. 8	....	170	90	200	55	600	15,000	48	72	...
" 9	....	180	85	200	60	600	10,000	53	70	...
" 10	....	180	65	180	60	....	15,000	63	67	...
" 11	2.4	170	65	160	60	....	4,500	62	63	...
" 12	2.6	160	90	160	75	100	6,500	44	53	...
" 13	2.6	170	85	175	90	1,300	15,000	50	49	...
" 14	2.7	150	100	170	75	850	8,500	33	56	...
" 15	2.9	150	70	165	60	650	6,000	53	64	...
" 16	3.1	180	90	185	85	550	220	50	54	60
" 17	3.0	160	100	175	145	600	375	30	17	37
" 18	3.0	170	140	205	125	800	950	18	39	...
" 19	3.0	220	150	265	110	350	6,000	32	58	...
" 20	3.1	250	130	260	100	60	13,000	50	62	...
" 21	2 9	200	110	240	95	250	27,000	45	60	...
" 22	2.7	200	85	235	115	950	15,000	58	51	...
" 23	2.8	160	85	205	135	1,000	12,000	47	34	...
" 24	3.0	170	100	210	100	650	550	41	52	15
" 25	3.4	150	100	175	65	750	600	33	63	20
" 26	3.8	160	90	195	70	700	650	44	64	7
" 27	4.2	160	90	200	75	500	1,200	44	62	...
" 28	4.6	170	80	210	80	600	300	52	62	50
" 29	5.0	180	80	230	85	600	800	55	63	...
" 30	5.4	190	90	285	70	650	5 200	53	77	...
" 31	5.4	210	110	325	60	550	17,000	48	81	...
Feb. 1	5.8	200	120	345	100	575	....	66	71	...
" 2	6.2	260	130	390	140	950	4,700	50	64	...
" 3	6.1	280	140	455	135	1,800	29 000	50	70	...
" 4	5.9	260	150	455	130	1,100	31,000	43	71	...
" 5	5.9	270	160	415	115	1,100	49,000	41	72	...
" 6	5.7	250	150	380	90	1,800	20,000	40	76	...
" 7	5.4	270	160	370	80	4,200	14.000	41	78	...
" 8	5.1	260	140	115	75	3,800	16,000	46	35	...
" 9	4.8	230	140	285	90	....	14,000	39	68	...
" 10	4.7	210	140	250	105	.....	9,500	33	58	...
" 11	4.8	220	130	250	106	6,000	1,200	41	60	80
" 12	4.7	200	140	245	90	2,300	4,800	30	63	...
" 13	4.5	210	140	255	90	2,500	6,100	33	65	...
" 14	4.5	210	140	265	90	2,100	1,800	33	66	14
" 15	4.5	220	140	290	95	4,500	2,000	36	67	56
" 16	4.7	220	140	270	105	3,400	....	36	61	...
" 17	4.8	210	130	295	100	....	....	38	66	...
" 18	5 0	210	100	275	75	....	1,000	52	73	...
" 19	5.2	210	120	275	95	....	....	43	65	...
" 20	5.4	220	95	275	70	....	1,400	57	74	...
" 21	4.7	210	110	290	85	3,100	1,300	48	71	58
" 22	4.9	230	100	285	95	3,000	950	56	67	68
" 23	5.9	230	130	290	105	2,800	1,800	44	64	36
" 24	5.8	220	140	280	115	2,000	6,000	36	59	...
" 25	5.6	220	140	290	115	1,200	9,500	36	60	...
" 26	5.7	250	140	360	110	1.200	5,500	44	70	...
" 27	5.3	260	130	310	110	2,200	6,000	50	65	...

TABLE No. XXX.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 1. Using 72 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil. River.	Silica Turbidity. Parts per mil. Sub-sided Water.	Suspended Matter. Parts per mil. River.	Suspended Matter. Parts per mil. Sub-sided Water.	Bacteria. Per cub. cent. River.	Bacteria. Per cub. cent. Sub-sided Water.	Average Efficiency of Subsiding Basin in % Removal of Silica Tur-bidity.	Average Efficiency of Subsiding Basin in % Removal of Sus-pended Matter.	Average Efficiency of Subsiding Basin in % Removal of Bac-teria.
Feb. 28	5.1	240	130	285	115	3,200	6,500	46	60	...
Mch. 1	5.1	230	120	255	100	3,800	3,200	48	61	16
" 2	4.7	210	110	240	85	2,800	4,900	48	65	...
" 3	4.4	190	110	205	80	1,700	2,200	42	61	...
" 4	4.3	190	85	215	75	1,400	1,900	55	65	...
" 5	4.1	190	95	210	80	1,600	350	50	62	73
" 6	4.0	180	90	190	80	2,400	550	50	58	77
" 7	3.8	180	85	225	80	1,500	400	55	64	73
" 8	3.4	210	95	260	75	1,100	350	55	56	68
" 9	3.1	180	90	210	70	1,000	425	50	67	57
" 10	2.8	180	75	180	65	750	200	58	64	73
" 11	2.6	170	60	155	55	800	190	65	65	76
" 12	2.6	200	60	230	45	950	350	70	80	63
" 13	2.8	180	35	165	65	600	15,000	80	61	...
" 14	2.3	160	70	140	90	600	1,200	56	36	...
" 15	2.0	150	65	150	90	700	6,000	57	40	...
" 16	2.0	140	50	150	60	750	3,000	64	60	...
" 17	1.8	130	70	140	50	750	5,000	46	64	...
" 18	1.7	130	60	140	40	600	4,500	54	71	...
" 19	1.7	110	50	115	30	500	2,700	55	74	...
" 20	1.7	110	40	90	19	700	3,500	64	79	...
" 21	2.3	120	40	105	17	1,100	2,800	67	84	...
" 22	3.0	150	40	240	15	800	3,400	73	94	...
" 23	4.1	170	45	205	12	900	2,200	73	94	...
" 24	5.0	210	30	285	9	1,500	9,500	85	97	...
" 25	6.0	300	12	405	50	800	6,500	96	87	...
" 26	7.3	500	90	715	90	....	800	82	87	...
" 27	7.8	525	140	670	55	3,000	1,100	73	93	63
" 28	8.4	625	25	815	19	6,500	425	96	98	93
" 29	8.6	825	60	1,010	105	6,500	1,100	93	90	83
" 30	8.7	950	300	1,100	185	6,000	1,600	67	83	73
" 31	8.8	975	475	1,250	230	3,800	2,500	52	82	34
April 1	9.0	1,000	400	1,200	290	1,400	2,600	61	76	...
" 2	9.2	1,000	375	1,120	305	2,900	1,000	63	73	65
" 3	9.3	950	450	1,100	320	....	2,900	54	71	...
" 4	9.5	900	350	930	315	5,000	2,100	61	66	58
" 7	9.5	650	325	805	260	4,500	1,500	50	68	67
" 8	9.4	650	325	745	240	3,800	1,500	50	68	61
" 9	9.4	650	325	640	225	3,200	1,600	50	65	50
" 10	9.3	600	325	610	245	3,200	1,500	46	60	53
" 11	9.3	625	350	670	255	4,300	1,600	44	67	68
" 12	9.4	725	300	695	255	5,000	1,700	57	64	66
" 13	9.6	675	300	680	260	4,700	1,100	55	62	77
" 14	9.7	625	325	695	255	3,600	1,100	48	63	69
" 15	10.0	550	350	620	250	2,200	2,000	36	60	9
" 16	10.4	600	400	735	275	4,400	1,700	33	63	61
" 17	10.5	475	400	650	300	3,900	....	16	54	...
" 22	11.3	600	325	795	225	2,500	41,000	45	65	...
" 23	11.2	600	280	730	225	3,900	41,000	53	69	...
" 27	11.6	575	270	605	190	2,800	16,500	53	68	...
" 28	11.7	625	290	620	220	3,700	12,000	53	65	...

TABLE No. XXX.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 1. Using 72 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Subsided Water.	River.	Subsided Water.	River.	Subsided Water.	Silica Turbidity.	Suspended Matter.	Bacteria.
April 29	11.8	650	240	690	250	3,700	2,800	63	64	38
" 30	12.0	675	400	805	235	3,100	1,600	46	71	48
May 1	12.2	700	325	800	220	4,100	2,800	54	72	32
" 2	12.1	775	325	835	215	3,400	2,000	58	74	41
" 3	12.2	725	290	805	215	2,400	1,900	60	73	21
" 4	12.3	725	230	755	210	4,600	2,800	68	72	39
" 5	12.3	700	260	745	210	3,000	1,200	62	72	60
" 6	12.5	700	220	740	200	2,800	1,100	68	73	61
" 7	12.4	650	250	620	185	3,400	1,100	61	70	70
" 8	12.6	600	220	590	205	2,100	1,300	63	65	28
" 11	12.4	525	170	515	125	2,600	1 300	68	74	50
" 12	12.6	525	150	485	125	3,300	2,700	71	74	18
" 13	12.4	500	170	445	125	2,100	500	67	72	76
" 14	12.5	525	180	440	120	3,000	1,000	66	73	67
" 15	12.6	500	150	510	115	4,500	1,100	69	77	75
" 16	12.4	475	170	450	130	1,700	700	64	71	59
" 17	12.7	400	130	430	140	1,800	350	68	68	80
" 18	12.7	400	140	405	120	2,400	750	65	70	69
" 19	12.6	400	120	415	105	2,200	475	70	75	78
" 24	12.5	300	80	350	65	1,000	1,900	73	81	...
" 25	12.0	260	80	300	65	1,100	3,500	69	78	...
" 26	11.6	260	80	315	70	1,200	1,200	69	78	...
" 27	11.3	260	80	305	80	1,300	1,200	69	74	8
" 28	10.8	250	80	325	85	2,200	750	68	74	66
" 29	10.3	270	90	330	95	2,500	600	67	71	76
" 30	9.8	260	90	310	90	3,200	700	65	71	78
" 31	9.1	270	95	315	85	1,800	500	65	73	72
June 3	7.6	300	75	335	90	1,000	400	75	73	60
" 4	7.3	375	85	385	90	1,400	300	77	77	79
" 5	7.1	525	85	545	95	3,600	2,400	77	82	33
" 6	6.9	425	90	445	100	1,400	475	74	78	66
" 7	6.8	600	85	670	85	2,500	2,000	86	80	20
" 8	7.1	625	80	630	70	3,400	1,100	87	89	68
" 9	7.0	550	95	525	70	2,900	650	83	87	78
" 10	7.1	525	95	540	75	3,000	600	82	86	80
" 11	7.2	500	85	520	65	2,800	500	83	88	82
" 12	7.6	500	70	485	60	3,300	....	86	88	...
" 13	7.8	425	80	455	70	2,100	....	81	85	...
" 14	8.1	500	100	480	75	2,800	550	80	84	80
" 15	8.4	450	110	460	75	3,100	800	75	84	74
" 16	8.7	400	110	415	80	2,200	....	73	81	...
" 17	8.7	450	120	430	80	1,400	450	73	82	68
" 18	8.6	475	140	450	80	1,200	800	70	82	33
" 20	7.8	450	100	390	85	950	325	78	78	66
" 21	7.6	400	110	385	85	800	230	72	78	71
" 22	7.5	350	120	360	90	1,200	325	66	75	73
" 23	7.2	350	130	390	95	1,300	350	63	75	73
" 24	7.1	400	130	445	95	950	....	67	79	...
" 25	7.1	400	130	395	95	1,200	650	67	76	46
" 26	6.9	375	130	355	95	1,600	800	65	73	50
" 27	6.8	400	120	375	85	2,000	1,000	70	77	50

TABLE No. XXX.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 1. Using 72 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
June 28	6.8	400	120	445	85	2,400	800	70	81	67
" 29	6.3	450	120	525	85	2,200	550	73	84	75
July 1	5.5	550	110	590	75	2,000	375	80	87	81
" 2	5.2	475	100	465	70	1,400	750	79	85	46
" 3	5.0	450	130	485	90	1,400	3,700	71	82	...
" 4	4.7	450	170	415	115	1,100	425	62	72	62
" 5	4.4	500	170	570	115	2,600	600	66	80	77
" 6	4.0	550	160	560	110	1,500	475	71	80	68
" 7	4.1	450	170	435	105	1,600	550	62	76	66
" 8	4.3	450	160	440	100	1,800	425	64	77	76
" 9	4.6	500	150	570	105	1,600	750	70	80	53
" 10	5.0	575	150	695	105	2,000	475	74	78	76
" 11	5.6	550	150	660	110	1,000	475	73	84	52
" 12	5.8	650	140	830	100	2,000	450	78	88	77
" 14	6.1	725	110	765	80	1,600	300	85	90	81
" 15	5.8	700	130	685	85	1,600	700	81	88	56
" 16	5.7	725	130	800	85	1,600	250	82	89	84
" 17	5.4	725	120	850	90	1,600	200	84	90	87
" 18	5.0	700	110	825	80	1,300	275	84	90	79
" 29	3.0	400	90	.....	.....	4,100	400	77	...	90
" 30	3.0	350	90	....	....	1,000	450	74	...	55
" 31	2.8	250	70	....	....	1,800	375	72	...	79
Aug. 1	2.7	260	80	....	....	1,200	375	69	...	69
" 2	2.4	220	90	....	....	2,200	350	59	...	84
" 3	2.2	190	90	....	....	1,300	1,400	53	...	...
" 4	2.1	160	90	....	....	1,100	600	44	...	45
" 5	2.0	160	75	....	....	900	325	53	...	64
" 6	1.9	160	75	....	....	850	600	53	...	30
" 7	1.9	160	70	.....	....	....	300	56	...	...
" 8	2.1	130	75	.....	....	....	475	42	...	...
" 9	2.2	150	60	....	.....	800	325	60	...	59
" 10	1.9	130	60	....	....	1,100	400	54	...	64
" 11	1.8	120	60	....	....	700	170	50	...	75
" 12	1.9	120	60	....	....	900	600	50	...	33
" 13	1.7	110	60	.....	.....	1,500	130	45	...	91
" 14	1.6	130	65	....	....	1,200	140	50	...	88
" 15	1.6	110	75	....	.....	450	190	32	...	58
" 16	1.7	95	80	....	.....	230	275	16	...	...
" 17	3.0	90	65	....	....	350	375	28	...	...

TABLE No. XXXI.

Showing the Operation and Efficiencies of Subsiding Basin No. 2. Using 6 Hours of Plain Subsidence.

DATE, 1901.	Stage of River.	Silica Turbidity.			DATE, 1901.	Stage of River.	Silica Turbidity.		
		River.	Subsided Water.	% of Removal.			River.	Subsided Water.	% of Removal.
April 22.	11.4	525	475	10	May 14.	12.7	400	375	6
" 23.	11.7	525	450	14	" 15.	12.7	400	375	6
" 24.	11.6	575	500	13	" 16.	12.6	400	350	12
" 25.	11.7	625	500	20	" 17.	12.6	375	325	13
" 26.	11.8	650	560	15	" 18.	12.6	350	325	7
" 27.	12.0	675	500	26	" 19.	12.6	325	300	8
" 28.	12.2	700	500	28	" 20.	12.5	325	275	15
" 29.	12.1	775	350	55	" 21.	12.5	300	270	10
" 30.	12.2	725	525	28	" 22.	12.0	260	230	12
May 1.	12.3	725	550	24	" 23.	11.6	260	240	8
" 2.	12.3	700	525	25	" 25.	10.8	250	220	12
" 3.	12.5	700	575	18	" 27.	9.8	260	190	27
" 4.	12.4	650	500	23	" 28.	9.1	270	200	26
" 5.	12.6	600	475	21	" 29.	8.4	250	210	16
" 6.	12.4	550	400	27	" 30.	8.0	300	220	27
" 7.	12.6	575	400	30	" 31.	7.6	300	230	23
" 8.	12.4	525	400	24	June 1.	7.3	375	270	28
" 9.	12.6	525	400	24	" 2.	7.1	525	300	43
" 10.	12.4	500	400	20	" 3.	6.9	425	350	18
" 11.	12.5	525	250	52	" 4.	6.8	600	350	42
" 13.	12.4	475	400	16	" 5.	7.1	625	350	44

NOTE—Silica Turbidity results given in Parts per Million.

TABLE No. XXXII.

Showing the Operation and Efficiencies of Subsiding Basin No. 2. Using 48 Hours of Plain Subsidence.

Date, 1900.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
Dec. 26	.....	350	170	400	145	1,200	27,000	52	64	...
" 27	.....	300	180	280	150	1,500	16,000	40	47	...
" 28	.....	270	90	300	95	1,800	39,500	67	68	...
" 29	.....	290	130	280	110	5,000	10,500	55	61	...
" 30	.....	270	130	160	190	2 000	6,000	52	...	...
" 31	.....	240	145	200	115	3,000	250,000	40	43	...
Jan. 1-1901	.....	230	150	230	115	1,900	70,000	35	50	...
" 2	.....	230	160	225	120	900	2,600	30	47	...
" 3	.....	220	140	215	130	500	3,100	36	39	...
" 4	.....	210	140	185	145	1,400	1,200	33	22	14
" 5	.....	180	150	190	110	7,500	700	17	42	91
" 6	.....	200	160	130	115	2 100	300	20	12	86
" 7	.....	170	150	200	120	600	....	12	40	...
" 8	.....	180	140	200	100	600	....	22	50	...
" 9	.....	180	95	180	80	....	2,300	47	55	...
" 10	2.4	170	110	160	90	....	2,400	35	44	...
" 11	2.6	160	100	160	95	100	14,000	38	41	...
" 12	2.6	170	120	175	100	1,300	14,000	29	43	...
" 13	2 7	150	120	170	100	850	7,800	20	41	...
" 14	2.9	150	110	165	105	650	3,900	27	36	...
" 15	3.1	180	110	185	105	550	1,700	39	43	...
" 16	3.0	160	95	175	125	600	130	41	29	78
" 17	3.0	170	140	205	150	800	325	18	27	59
" 18	3.0	220	160	265	125	350	1,400	27	53	...
" 19	3.1	250	140	260	105	60	1,900	44	60	...
" 20	2.9	200	130	240	100	225	2,000	35	58	...
" 21	2.7	200	100	235	95	950	2,300	50	59	...
" 22	2.8	160	100	205	100	1,050	3,100	38	50	...
" 23	3.0	170	110	210	100	700	2,300	35	52	...
" 24	3.4	150	100	175	110	800	1,050	33	37	...
" 25	3.8	160	130	195	115	700	800	19	41	...
" 26	4.2	160	120	200	95	500	900	25	52	...
" 27	4.6	170	85	210	75	600	450	50	64	25
" 28	5.0	180	120	230	90	600	300	33	61	50
" 29	5.4	190	100	285	100	650	300	47	65	54
" 30	5.4	210	110	325	120	600	1,000	48	76	...
" 31	5.8	200	160	345	140	600	1,700	20	59	...
Feb. 1	6.2	260	170	390	130	1,000	1,700	35	67	...
" 2	6.1	280	140	455	120	1,900	1,000	50	74	47
" 3	5.9	260	190	455	145	1,100	1,200	27	68	...
" 4	5.9	270	180	415	175	1,100	3,000	33	58	...
" 5	5.7	250	170	380	165	1 800	2,800	32	57	...
" 6	5.4	270	180	370	150	4,200	3,000	33	60	29
" 7	5.1	260	120	315	110	3,800	....	54	65	...
" 8	4.8	230	140	285	70	4,300	5,000	39	75	...
" 9	4.7	210	120	250	95	4,800	5,500	43	62	...
" 10	4.8	220	160	250	115	6,000	500	27	54	92
" 11	4.7	200	85	245	105	2,300	1,000	58	57	56
" 12	4.5	210	110	255	255	2,500	1,800	48	65	28
" 13	4.5	210	150	265	265	2,100	2,100	28	62	...
" 14	4.5	220	180	290	290	4,500	....	18	67	...

TABLE No. XXXII.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 2. Using 48 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Subsided Water.	River.	Subsided Water.	River.	Subsided Water.	Silica Turbidity.	Suspended Matter.	Bacteria.
Feb. 15	4.7	220	140	270	100	3,400	....	50	63	...
" 16	4.8	210	100	295	95	....	....	52	68	...
" 17	5.0	210	110	275	100	....	....	48	64	...
" 18	5.2	210	120	275	100	....	4,700	43	64	...
" 19	5.4	220	130	275	110	....	4,900	41	60	...
" 20	4.7	210	160	290	115	3,100	19,000	24	60	...
" 21	4.9	230	130	285	115	3,000	2,800	43	60	7
" 22	5.9	230	140	290	100	2,800	2,200	44	65	21
" 23	5.8	220	170	280	115	2,000	2,100	23	59	...
" 24	5.6	220	170	290	130	1,200	....	23	55	...
" 25	5.7	250	160	360	115	1,200	2,300	36	68	...
" 26	5.3	260	150	310	105	2,200	2,900	42	66	...
" 27	5.1	240	130	285	115	3,200	1,900	46	60	37
" 28	5.1	230	140	255	125	3,800	1,800	39	51	53
Mar. 1	4.7	210	95	240	100	2,800	1,000	55	58	64
" 2	4.4	190	85	205	75	1,700	1,100	55	63	35
" 3	4.3	190	95	215	75	1,400	1,200	50	65	14
" 4	4.1	190	95	210	80	1,600	1,000	50	62	31
" 5	4.0	180	130	190	95	2,400	650	28	50	73
" 6	3.8	180	140	225	110	1,500	850	22	51	43
" 7	3.4	210	120	260	125	1,100	650	43	52	41
" 8	3.1	180	95	210	135	1 000	400	42	36	60
" 9	2.8	180	120	180	100	750	425	33	45	43
" 10	2.6	170	100	155	70	800	600	41	53	25
" 11	2.6	200	110	230	70	950	425	45	70	55
" 12	2.8	180	85	165	70	600	550	42	58	8
" 13	2.3	160	60	140	85	600	1,900	62	39	...
" 14	2.0	150	100	150	100	700	500	32	33	29
" 15	2.0	140	100	150	85	800	425	29	43	47
" 16	1.8	130	80	140	70	750	800	39	50	...
" 17	1.7	130	80	140	60	600	2,100	39	57	...
" 18	1.7	110	75	115	50	500	2,400	32	57	...
" 19	1.7	110	70	90	40	700	900	36	55	...
" 20	2.3	120	70	105	35	1,100	1 700	42	67	...
" 21	3.0	150	75	240	35	800	2,500	50	85	...
" 22	4.1	170	70	205	40	900	4,200	59	80	...
" 23	5.0	210	65	285	33	1,600	7,500	69	88	...
" 24	6.0	300	40	405	26	800	14,500	87	93	...
" 25	7.3	500	35	715	70	....	10,500	93	90	...
" 26	7.8	525	160	670	120	3,000	1,300	76	82	57
" 27	8.4	625	210	815	130	6,500	3,800	66	84	42
" 28	8.6	825	210	1,010	145	6,500	3,900	74	86	40
" 29	8.7	950	325	1,100	180	6,000	2,100	66	84	65
" 30	8.8	975	280	1,250	220	3,800	850	71	82	78
" 31	9.0	1,000	240	1,200	280	1,400	1,300	76	77	7
Apr. 1	9.2	1,000	450	1,120	340	2,900	3,400	55	70	...
" 2	9.3	950	375	1,100	345	....	1,300	60	69	...
" 3	9.5	900	450	930	345	5,000	2,700	50	63	46
" 4	9.6	750	400	815	290	4,800	2,800	47	64	42
" 5	9.5	675	350	780	240	4,000	1,700	47	69	58
" 6	9.5	650	375	805	245	4,500	2,100	42	69	53

TABLE No. XXXII.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 2. Using 48 Hours of Plain Subsidence

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
Apr. 7	9.4	650	400	745	250	3,800	1,400	39	67	63
" 8	9.4	650	270	640	220	3,200	1,100	58	66	66
" 9	9.3	600	270	610	185	3,200	1,700	55	70	47
" 10	9.3	625	250	670	175	4,300	1,100	60	74	75
" 11	9.4	725	170	695	160	5,100	1,700	76	77	67
" 12	9.6	675	130	680	160	4,700	750	81	76	84
" 22	11.2	600	325	730	200	3,900	14 000	46	73	...
" 23	11.2	550	300	605	200	3,100	4,600	45	67	...
" 24	11.4	525	350	645	210	2,100	2,500	33	67	...
" 25	11.7	525	325	530	220	1,700	2,600	38	58	...
" 26	11.6	575	325	605	270	2,800	2 000	44	55	29
" 27	11.7	625	350	620	325	3,700	3,100	44	48	16
" 28	11.8	650	400	690	290	3,700	3,800	39	58	...
" 29	12.0	675	350	805	260	3,100	1,800	48	68	42
" 30	12.2	700	375	800	290	4,100	1.100	46	64	73
May 1	12.1	775	425	835	320	3,400	3,300	45	62	29
" 2	12.2	725	325	805	280	2,400	1,700	55	65	29
" 3	12.3	725	350	755	245	4,600	1,700	52	67	63
" 4	12.3	700	400	745	260	3,000	1,700	43	68	43
" 5	12.5	700	375	740	275	2,800	700	46	63	75
" 6	12.4	650	350	620	260	3,400	1,500	46	58	56
" 7	12.6	600	350	590	240	2,100	1,600	42	59	24
" 8	12.4	550	325	490	230	1,600	2,200	41	53	...
" 9	12.6	575	290	480	225	1,400	1,800	49	53	...
" 10	12.4	525	325	515	....	2,600	2,300	38	...	12
" 11	12.6	525	300	485	215	3,300	1,200	39	56	64
" 13	12.5	525	290	440	195	3,000	....	45	56	...
" 14	12.6	500	300	510	195	4,500	1,100	40	62	75
" 15	12.4	475	280	450	200	1,700	1,700	41	56	...
" 16	12.7	400	260	430	205	1,800	1,400	35	52	22
" 17	12.7	400	260	405	210	2,400	2,400	35	48	...
" 18	12.6	400	250	415	185	2,200	1,500	38	55	32
" 19	12.6	375	180	385	160	1,000	900	52	58	10
" 20	12.6	350	210	375	160	2,300	750	40	57	67
" 21	12.6	325	210	325	165	1,700	800	35	49	53
" 22	12.5	325	190	375	150	1,200	800	42	60	38
" 23	12.5	300	170	350	135	1,000	1,100	43	62	...
" 25	11.6	260	150	315	115	1,200	1,900	42	69	...
" 26	11.3	260	160	305	125	1,300	1,600	38	59	...
" 27	10.8	250	160	325	135	2,200	1,700	36	58	23
" 28	10.3	270	170	330	145	2,500	1.400	37	56	44
" 29	9.8	260	170	310	160	3,200	1 300	35	48	59
" 30	9.1	270	180	315	140	1,800	800	33	56	55
" 31	8.4	250	160	325	120	1,200	475	36	63	61
June 1	8.0	300	160	335	135	1,500	650	47	60	57
" 2	7.6	300	180	335	155	1,000	500	40	54	50
" 3	7.3	375	170	385	145	1,400	900	55	62	36
" 4	7.1	525	150	545	135	3,600	....	71	74	...
" 5	6.9	425	170	445	....	1,400	....	60	...	...

TABLE No. XXXIII.

Showing the Operation and Efficiencies of Subsiding Basin No. 3. Using 12 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
May 14	12.7	400	350	430	285	1,200	1,800	12	34	...
" 15	12.7	400	325	405	255	2,400	1,300	19	37	46
" 16	12.6	400	300	415	245	2,200	425	25	41	35
" 17	12.6	875	290	385	240	1,000	....	28	37	...
" 18	12.6	350	270	375	230	2,300	2,200	23	39	44
" 19	12.6	325	280	325	220	1,700	1,100	20	32	35
" 20	12.5	325	270	375	220	1,200	1,200	17	41	...
" 21	12.5	300	270	350	215	1,000	1,000	10	39	...
" 22	12.0	260	230	300	195	1,100	1,100	12	35	...
" 23	11.6	280	210	315	180	1 200	900	19	43	25
" 24	11.3	260	190	305	.....	1,300	1,100	27	...	15
" 25	10.8	250	200	325	150	2 200	....	20	54	...
" 26	10.3	270	190	330	160	2,500	1,600	30	52	36
" 27	9.8	260	190	210	170	3,200	2,100	27	45	52
" 28	9.1	270	190	315	175	1,800	1,200	30	44	33
" 29	8.4	250	180	325	180	1,200	1,400	28	45	...
" 30	8.0	300	190	335	165	1,000	1,200	37	51	...
" 31	7.6	300	200	335	150	1,000	650	33	55	35
June 1	7.3	375	220	385	200	1,400	950	41	48	32
" 2	7.1	525	300	545	255	3,600	1,100	43	53	70
" 3	6.9	425	280	445	250	1,400	700	34	44	50
" 4	6.8	600	270	670	250	2,500	1,700	55	63	32
" 5	7.1	625	280	630	245	3,400	2,500	55	61	26
" 6	7.0	550	260	525	240	2,900	1,900	53	54	34
" 7	7.1	525	270	540	215	3 000	1,900	43	60	37
" 27	5.9	475	300	570	210	2,100	1,600	37	59	24
" 28	5.5	550	300	590	210	2,000	1,000	46	66	50
" 29	5.2	475	325	465	230	1,400	1,300	31	51	7
" 30	5.0	450	350	485	245	1,400	900	22	50	36
July 1	4.7	450	350	415	275	1,100	850	22	34	23
" 2	4.4	500	375	570	290	2,600	1,300	25	49	50
" 3	4.0	550	375	560	290	1,500	1,600	32	53	...
" 4	4.1	450	350	435	275	1,600	1,300	22	37	19
" 5	4.3	450	350	440	275	1,800	1,300	22	38	28
" 6	4.6	500	350	570	275	1,600	1,200	30	52	25
" 12	5.8	700	450	685	315	1,600	850	36	54	47
" 13	5.7	725	450	800	350	1,600	1,600	38	56	...
" 14	5.4	725	400	850	310	1,600	1,200	45	64	25
" 15	5.0	700	400	825	300	1,300	1,000	43	64	15
" 16	4.5	700	375	735	285	3,300	1,000	46	61	70
" 17	4.0	775	400	890	310	1,400	1,100	48	65	22
" 18	3.6	750	475	785	370	2,400	2,200	37	53	8
" 19	3.3	675	450	650	315	2,200	1,800	33	52	18
" 20	3.0	550	375	465	260	2,200	1,100	32	44	50

TABLE No. XXXIV.

Showing the Operation and Efficiencies of Subsiding Basin No. 3. Using 48 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
Jan. 2.......	3.6	230	160	225	105	900	2,700	30	53	...
" 3.......	3.5	220	160	215	120	500	9,200	27	44	...
" 4.......	3.2	210	160	185	205	1,800	2,800	24	...	...
" 5.......	2.8	180	160	190	175	7,500	2,000	11	8	73
" 6.......	2.7	200	160	130	150	2,100	1,600	20	...	24
" 7.......	2.4	170	160	200	120	600	....	6	40	...
" 8.......	2.3	180	140	200	120	600	1,400	22	40	...
" 9.......	2.3	180	120	180	115	....	1 300	33	36	...
" 10.......	2.4	170	130	160	105	....	4,400	23	34	...
" 11.......	2.6	160	120	160	95	100	3,500	25	41	...
" 12.......	2.6	170	120	175	100	1,300	3,800	29	43	...
" 13.......	2.7	150	130	170	100	850	1,500	13	41	...
" 14.......	2.9	150	120	165	100	650	2,100	20	39	...
" 15.......	3.1	180	120	185	100	550	1,100	33	46	...
" 16.......	3.0	160	120	175	130	600	230	25	26	62
" 17.......	3.0	170	170	205	160	800	350	...	22	56
" 18.......	3.0	220	160	265	150	350	275	27	43	21
" 19.......	3.1	250	170	260	135	60	1,500	32	48	...
" 20.......	2.9	200	150	240	135	225	1,000	25	44	...
" 21.......	2.7	200	130	235	130	950	750	35	45	21
" 22.......	2.8	160	130	205	115	1,000	700	19	44	30
" 23.......	3.0	170	130	210	105	700	600	23	50	14
" 24.......	3.4	150	120	175	110	800	450	20	37	44
" 25.......	3.8	160	130	195	120	700	375	19	38	46
" 26.......	4.2	160	130	200	130	500	425	19	35	15
" 27.......	4.6	170	130	210	145	600	450	23	31	25
" 28.......	5.0	180	140	230	130	600	425	22	44	29
" 29.......	5.4	190	130	285	120	650	375	32	58	42
" 30.......	5.4	210	150	325	150	600	700	29	54	...
" 31.......	5.8	200	170	345	180	600	1,000	15	48	...
Feb. 1.......	6.2	260	190	390	170	1,000	1.000	27	56	...
" 2.......	6.1	280	190	455	155	1,900	1,200	32	66	37
" 9.......	4.7	210	150	250	135	4,800	3,500	29	46	27
" 10.......	4.8	220	170	250	135	6,000	2,200	23	46	63
" 11.......	4.7	200	140	245	135	2,300	3,500	30	45	...
" 12.......	4.5	210	170	255	135	2,500	3,200	19	47	...
" 13.......	4.5	210	180	265	130	2,100	2,700	14	51	...
" 14.......	4.5	220	170	290	120	4,500	....	23	59	...
" 15.......	4.7	220	160	270	115	3,400	....	27	57	...
" 16.......	4.8	210	160	295	105	....	....	24	64	...
" 17.......	5.0	210	160	275	140	....	....	24	49	...
" 18.......	5.2	210	150	275	130	....	....	29	53	...
" 19.......	5.4	220	140	275	120	....	....	36	56	...
" 20.......	4.7	210	160	290	140	3,100	3,300	24	52	...
" 21.......	4.9	230	180	285	140	3,000	4,900	22	52	...
" 22.......	5.9	230	160	290	140	2,800	1,800	30	52	36
" 23.......	5.8	220	170	280	155	2,000	....	23	44	...
" 24.......	5.6	220	170	290	170	1,200	12 000	23	41	...
" 25.......	5.7	250	180	360	165	1,200	4,000	28	54	...
" 26.......	5.3	260	170	310	160	2,200	3,300	35	48	...
" 27.......	5.1	240	160	285	150	3,200	1,900	33	47	41

TABLE No. XXXIV.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 3. Using 48 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
Feb. 28	5.1	230	160	255	140	3,800	1,600	30	45	58
Mar. 1	4.7	210	140	240	130	2,800	1,300	33	46	54
" 2	4.4	190	130	205	120	1,700	1,900	32	42	...
" 3	4.3	190	120	215	115	1,400	3,300	37	46	...
" 4	4.1	190	120	210	110	1,600	1,400	37	48	13
" 5	4.4	180	150	190	115	2,400	950	17	40	60
" 6	3.8	180	150	225	125	1,500	750	17	45	50
" 7	3.4	210	130	260	120	1,100	1,100	38	54	...
" 8	8.1	180	130	210	120	1,000	800	28	43	20
" 9	2.8	180	130	180	105	750	475	28	42	30
" 10	2.6	170	130	155	90	800	500	23	42	38
" 11	2.6	200	110	230	90	950	325	45	61	66
" 12	2.8	180	110	165	95	600	650	39	42	...
" 13	2.3	160	80	140	100	600	800	50	28	...
" 14	2.0	150	110	150	110	700	900	27	27	...
" 15	2.0	140	100	150	100	800	550	29	33	31
" 16	1.8	130	95	140	90	750	325	27	36	57
" 17	1.7	130	100	140	75	600	2,500	23	46	...
" 18	1.7	110	80	115	60	500	750	27	48	...
" 19	1.7	110	85	90	60	700	550	23	33	21
" 20	2.3	120	90	105	65	1,100	700	25	38	36
" 21	3.0	150	85	240	60	800	1,400	43	75	...
" 22	4.1	170	90	205	60	900	4,000	47	71	...
" 23	5.0	210	120	285	65	1,600	7,500	43	77	...
" 24	6.0	300	140	405	70	800	13,000	53	83	...
" 25	7.3	500	160	715	130	....	5,500	68	82	...
" 26	7.8	525	250	670	190	3,000	2,400	52	72	20
" 27	8.4	625	375	815	370	6,500	6,000	40	54	...
" 28	8.6	825	375	1,010	540	6,500	2,800	55	46	57
" 29	8.7	950	450	1,100	470	6,000	3,900	53	57	35
" 30	8.8	975	475	1,250	400	3,800	2,400	56	68	37
" 31	9.0	1,000	525	1,200	400	1,400	4,100	47	67	...
April 1	9.2	1,000	525	1,120	400	2,900	1,700	47	63	41
" 2	9.3	950	500	1,100	385	....	2,700	47	65	...
" 3	9.5	900	450	930	370	5,000	2,700	50	60	46
" 4	9.6	750	425	815	345	4,800	2,200	43	58	54
" 5	9.5	675	450	780	325	4,000	2,100	33	58	48
" 6	9.5	650	400	805	305	4,500	1,900	39	62	58
" 7	9.4	650	400	745	290	3,800	2,000	39	61	48
" 8	9.4	650	425	640	285	3,200	2,300	35	55	28
" 9	9.3	600	375	610	275	3,200	1,800	38	55	44
" 10	9.3	625	400	670	275	4,300	1,400	36	59	67
" 11	9.4	725	350	695	....	5,100	1,900	52	...	63

TABLE No. XXXV.

Showing the Operation and Efficiencies of Subsiding Basin No. 4. Using 12 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
May 25.......	10.8	250	190	325	155	2,200	....	24	52	...
" 26.......	10.3	270	180	330	150	2,500	2,300	33	55	8
" 27.......	9.8	260	170	310	145	3,200	2,000	35	53	37
" 28.......	9.1	270	190	315	170	1,800	550	30	46	69
" 29.......	8.4	250	190	325	200	1,200	1,400	24	38	...
" 30.......	8.0	300	210	335	200	1,500	1,100	30	40	27
" 31.......	7.6	300	210	335	200	1,000	550	30	40	45
June 1.......	7.3	375	230	385	220	1,400	750	39	43	46
" 2.......	7.1	525	300	545	245	3,600	750	43	55	79
" 3.......	6.9	425	325	445	245	1,400	700	23	45	50
" 4.......	6.8	600	300	670	245	2,500	....	50	63	...
" 5.......	7.1	625	300	630	255	3,400	2,900	52	60	15
" 6.	7.0	550	300	525	260	2,900	2,100	45	51	28
" 7.......	7.1	525	325	540	225	3,000	1,000	38	58	67
" 8.......	7.2	500	270	520	190	2,800	1,700	46	63	39
" 9.......	7.6	500	270	485	200	3,300	1,300	46	59	60
" 10.......	7.8	425	290	455	215	2,100	1,400	32	53	33
" 11.......	8.1	500	300	480	225	2,800	950	40	53	66
" 12.......	8.4	450	325	460	230	3,100	1,400	28	50	55
" 13.......	8.7	400	325	415	220	2,200	1,500	19	47	32
" 14.......	8.7	450	325	430	205	1,400	900	28	52	36
" 15.......	8.6	475	350	450	225	1,200	1,500	26	50	...
" 16.......	8.2	450	350	450	250	1,600	....	22	44	...
" 17.......	7.8	450	325	390	250	950	1,000	28	36	...
" 18.......	7.6	400	290	385	250	800	1,100	27	35	...
" 19.......	7.5	350	290	360	225	1,200	600	17	38	50
" 20.......	7.2	350	260	390	200	1,300	950	26	49	27
" 21.......	7.1	400	280	445	215	950	850	30	52	10
" 22.......	7.1	400	280	395	230	1,200	1,000	30	42	17
" 23.......	6.9	375	300	355	175	1,600	....	20	51	...
" 24.......	6.8	400	250	375	150	2,000	....	32	60	...
" 25.......	6.8	400	210	445	125	2,400	1,400	48	72	42
" 26.......	6.3	450	280	525	165	2,200	1,600	38	68	27
" 27.......	5.9	475	300	570	175	2,100	1,900	37	76	10
" 28.......	5.5	550	300	590	175	2,000	1,300	45	70	35
" 29.......	5.2	475	290	465	170	1,400	1,600	39	63	...
" 30.......	5.0	450	350	485	205	1,400	1,200	22	58	14
July 1.......	4.7	450	375	415	320	1,100	800	17	23	27
" 2.......	4.4	500	400	570	340	2,600	1,500	20	40	42
" 3.......	4.0	550	375	560	320	1,500	1,100	32	43	27
" 4.......	4.1	450	375	435	320	1,600	1,000	17	26	38
" 5.......	4.3	450	350	440	300	1,800	1,600	22	32	11
" 6.......	4.6	500	375	570	320	1,600	1,400	25	44	13
" 7.......	5.0	575	400	695	315	2,000	1,200	30	55	40
" 8.......	5.6	550	400	660	315	1 000	900	27	52	10
" 9.......	5.8	650	375	830	310	2,000	1,100	42	63	45
" 10.......	6.0	675	350	805	285	1,900	24,000	48	65	...
" 11.......	6.1	725	325	765	255	1,600	2,100	55	67	...
" 12.......	5.8	700	370	685	295	1,600	1,300	47	57	19
" 13.......	5.7	725	375	808	285	1,600	1,300	48	64	19
" 14.......	5.4	725	280	850	215	1,600	700	61	75	56

TABLE No. XXXV.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 4. Using 12 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
July 15.......	5.0	700	250	825	170	1.300	800	64	79	39
" 16........	4.5	700	220	735	150	3,300	500	68	80	85
" 17........	4.0	775	300	890	200	1,400	850	61	78	39
" 18.......	3.6	750	325	785	220	2,400	1,500	57	77	38
" 19.......	3.3	675	400	650	280	2,200	1,800	41	57	18
" 20.......	3.0	550	375	465	260	2,200	1,200	32	44	45
" 21.	3.0	475	325	345	250	1,500	1,500	11	27	...
" 22......	3.0	450	260	520	200	1,400	1,200	42	62	14
" 23.......	2.9	350	180	265	140	2,500	1,000	49	47	60
" 24.......	2.8	325	250	255	195	2,100	1,500	23	24	29
" 25.......	3.0	325	190	255	145	1,400	1,700	42	43	...
" 26.......	3.0	400	230	315	180	4,100	1,100	43	43	73
" 27.......	3.0	350	220	285	170	1,000	750	37	40	25
" 29.......	2.7	260	180	180	140	1,200	1,600	31	22	...
" 30.......	2.4	220	200	175	155	2 200	1,800	9	11	18
" 31.... ..	2.2	190	150	115	115	1,300	1 000	21	0	23
Aug. 1. ...	2.1	160	150	115	115	1,100	3,300	6	0	...

TABLE No. XXXVI.

ng the Operation and Efficiencies of Subsiding Basin No. 4.
Using 24 Hours of Plain Subsidence.

Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
	River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Turbidity.	Suspended Matter.	Bacteria.
3.6	230	170	225	135	900	....	26	40	...
3.5	220	160	215	130	500	1,900	27	40	...
3.2	210	150	185	120	1,800	2 000	29	35	...
2.8	180	160	190	125	7,500	2,900	11	34	55
2.7	200	180	130	145	2,100	850	10	...	60
2.4	170	170	200	150	600	850	...	25	...
2.3	180	170	200	150	600	....	6	25	...
2.3	180	150	180	130	....	....	17	28	...
2.4	170	150	160	110	....	1,100	12	31	...
2.6	160	120	160	105	100	1,700	25	34	...
2.6	170	130	175	105	1,300	1,700	24	40	...
2.7	150	140	170	105	850	450	7	38	47
2.9	150	130	165	110	650	1,300	13	33	...
3.1	180	130	185	110	550	850	28	41	...
3.0	160	130	175	110	600	375	19	37	38
3 0	170	130	205	150	800	110	24	27	86
3.0	220	190	265	190	350	500	14	28	...
3.1	250	160	260	180	60	650	36	31	...
2.9	200	170	240	165	225	800	15	31	...
2.7	200	160	235	150	950	1,500	20	36	...
2.8	160	150	205	135	1,000	750	6	34	25
3.0	170	150	210	110	700	850	12	48	...
3.4	150	140	175	85	800	1,300	7	51	...
3.8	160	130	195	110	700	325	19	44	54
4.2	160	150	200	130	500	350	6	35	30
4.6	170	140	210	135	600	750	18	36	...
5.0	180	150	230	135	600	425	17	41	29
5.4	190	150	285	135	650	450	21	53	31
5.4	210	130	325	140	600	300	38	57	50
5.8	200	180	345	165	600	800	10	52	...
6.2	260	190	390	195	1,000	1,100	27	50	...
6.1	280	200	455	200	1,900	1,500	40	56	21
5.9	260	200	455	200	1,100	850	23	56	23
5.9	270	210	415	200	1,100	2 200	22	52	...
5.7	250	210	380	195	1,800	3,000	16	49	...
5.4	270	200	370	205	4,200	3,300	26	45	21
5.1	260	210	315	215	3,800	1.400	19	32	63
4.8	230	190	285	165	4,300	....	17	42	...
4.7	210	180	250	115	4,800	3,600	14	54	25
4.8	220	180	250	140	6,000	4,300	18	44	28
4.7	200	190	245	170	2,300	1,900	5	31	17
4.5	210	190	255	165	2,500	1,200	10	35	52
4.5	210	180	265	165	2,100	3,400	14	38	...
4.5	220	170	290	160	4,500	1,700	23	45	62
4.7	220	180	270	150	3,400	....	18	44	...
4.8	210	170	295	140	....	....	19	52	...
5.0	210	180	275	130	....	....	14	53	...
5.2	210	170	275	150	....	....	19	45	...
5.4	220	130	275	110	....	2,800	41	60	...
4.7	210	150	290	130	3,100	....	29	55	...
4.9	230	180	285	165	3,000	3,200	22	42	...

TABLE No. XXXVI.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 4. Using 24 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
Feb. 21	5.9	230	170	290	155	2,800	2,000	26	47	29
" 22	5.8	220	170	280	140	2,000	2,700	23	50	...
" 23	5.6	220	190	290	165	1,200	....	14	43	...
" 24	5.7	250	190	360	185	1,200	4,600	24	49	...
" 25	5.3	260	190	310	175	2 200	3,000	19	44	...
" 26	5.1	240	170	285	165	3,200	3,000	29	42	6
" 27	5.1	230	180	255	155	3,800	2,600	22	39	32
" 28	4.7	210	170	240	150	2,800	1,900	19	38	32
Mch. 1	4.4	190	160	205	135	1,700	1,700	16	34	...
" 2	4.3	190	140	215	120	1,400	1,400	26	44	...
" 3	4.1	190	140	210	120	1,600	2,500	26	43	...
" 4	4.0	180	150	190	120	2,400	1,800	17	37	25
" 5	3.8	180	170	225	135	1,500	850	6	40	44
" 6	3.4	210	170	260	150	1,100	900	19	42	18
" 7	3.1	180	150	210	140	1,000	750	17	33	25
" 8	2.8	180	140	180	135	750	800	22	25	...
" 9	2.6	170	140	155	125	800	650	18	19	19
" 10	2.6	200	140	230	115	950	950	30	50	...
" 11	2.8	180	150	165	110	600	600	28	33	...
" 12	2.3	160	130	140	105	600	950	19	25	...
" 13	2.0	150	120	150	90	700	800	20	40	...
" 14	2.0	140	110	150	70	800	950	22	53	...
" 15	1.8	130	110	140	85	750	700	15	39	67
" 16	1.7	130	110	140	100	600	750	15	29	...
" 17	1.7	110	100	115	85	500	1,000	9	26	...
" 18	1.7	110	95	90	70	700	500	14	22	29
" 19	2.3	120	100	105	90	1,100	475	17	14	57
" 20	3.0	150	120	240	115	800	600	20	52	25
" 21	4.1	170	130	205	125	900	1,100	24	39	...
" 22	5.0	210	160	285	135	1,600	1,700	24	53	...
" 23	6.0	300	230	405	180	800	....	23	56	...
" 24	7.3	500	270	715	225	....	....	46	68	...
" 25	7.8	525	230	670	280	3,000	4,300	56	58	...
" 26	8.4	625	450	815	335	6,500	3,100	20	59	52
" 27	8.6	825	550	1,010	540	6,500	4,900	33	46	25
" 28	8.7	950	650	1,100	750	6,000	4,000	32	32	33
" 29	8.8	975	700	1,250	660	3,800	2,100	28	47	45
" 30	9.0	1,000	575	1,200	575	1,400	1,900	43	52	...
" 31	9.2	1,000	850	1,120	540	2,900	4,900	15	52	...
April 1	9.3	950	625	1,100	500	....	3,500	34	55	...
" 2	9.5	900	575	930	455	5,000	3,700	36	51	26
" 3	9.6	750	575	815	410	4 800	4,200	23	50	12
" 4	9.5	675	500	780	395	4,000	3,400	26	49	15
" 5	9.5	650	500	805	380	4,500	2,600	23	53	42
" 6	9.4	650	500	745	330	3,800	2,600	23	55	32
" 7	9.4	650	375	640	285	3,200	1,600	42	55	50
" 8	9.3	600	425	610	350	3,200	2,700	29	43	16
" 9	9.3	625	475	670	410	4,300	3,100	24	39	28
" 10	9.4	725	475	695	390	5 100	3,700	35	44	27
" 11	9.6	675	500	680	370	4,700	3,100	26	46	34
" 12	9.7	625	425	695	355	3,600	2,100	32	49	42

TABLE No. XXXVI.—Continued.

Showing the Operation and Efficiencies of Subsiding Basin No. 4. Using 24 Hours of Plain Subsidence.

Date, 1901.	Stage of River.	Silica Turbidity. Parts per mil.		Suspended Matter. Parts per mil.		Bacteria. Per cub. cent.		Average Efficiency of Subsiding Basin in % Removal of		
		River.	Sub-sided Water.	River.	Sub-sided Water.	River.	Sub-sided Water.	Silica Tur-bidity.	Sus-pended Matter.	Bac-teria.
April 13	10.0	550	400	620	340	2,300	2,400	27	45	...
" 14	10.4	600	400	735	320	4,400	1,800	33	56	59
" 15	10.5	475	425	650	300	3,900	2,600	11	54	33
" 16	10.6	450	400	645	320	3,500	1,700	11	50	52
" 17	10.7	600	500	645	335	3,400	....	17	48	...
" 18	11.0	600	460	720	335	....	....	23	53	...
" 19	11.8	575	425	850	340	4,000	1,300	26	60	67
" 20	11.3	600	400	795	350	2,500	2,700	33	56	...
" 21	11.2	600	400	730	340	3,900	4,100	33	53	...
" 22	11.2	550	375	605	310	3,100	2,000	32	49	36
" 23	11.4	525	400	645	285	2,100	2,700	24	56	...

With regard to the interpretation of the foregoing data, to show the degree of removal of suspended matter which could be expected in subsiding basins in practice, it is necessary to give consideration to a number of factors which appreciably influence the results obtained. Among the more prominent of these factors are the size and arrangement of the subsiding basins; the amount and character of the suspended matter in the river water; the temperature, both of the air and water; the increase in the latter as the water passes through the basins; the effect of wind action; as well as the period of subsidence.

The first point to be considered is that of the size of the basins used during these investigations. As already mentioned, these were much smaller than those which would be used in practice, consequently the obtained results were better. This is indicated clearly by the fact that of the several basins of this investigation, the smaller ones uniformly gave relatively better results than did the larger ones. The reason of this lies in the fact that the smaller basins had a relatively larger area of sides and bottom in proportion to the period of storage. Consequently, proportionately more friction existed, which tended to reduce the vortexial movements of the particles in suspension. Another point refers to the algæ growths which covered the sides of the basins, and which also helped to increase the friction of the same. Accordingly, it is necessary to give most weight to the results which were obtained from the largest of the test basins.

The temperature of the water has a marked effect upon the degree of removal of suspended matter, higher efficiencies being obtained during the summer than during the winter. Therefore, it is necessary

to bear in mind that the efficiencies obtained during the summer months could hardly be expected as an annual average.

Under local conditions, a feature was encountered which differs considerably from that generally observed elsewhere. For about six months in the year, beginning in January, the temperature of the water is colder than that of the air. As the water is stored in the basins, the air warms the surface strata of the water, and if the period of storage is sufficient there results a marked stratification of the water, the colder and more turbid water being found at the bottom, and the warmer and clearer water being found at the top. In the basin having a storage period of 72 hours this stratification was clearly notable from about the first of January until the end of June. Stratification, however, did not take place for so large a part of the year in the basins which had shorter periods of storage. The effect of this stratification is illustrated by the results recorded in the following table:

TABLE No. XXXVII.

Showing Variations of Turbidity and Temperature of Water in Subsiding Basins at Various Depths.

Date. Hour. 19[illegible]	Basin	Depth Feet	River Water Silica Turbidity	River Water Temperature Degrees F.	Inlet End Silica Turbidity	Inlet End Temperature Degrees F.	Outlet End Silica Turbidity	Outlet End Temperature Degrees F.
March [illegible] 10	S. S. 1.	0	[illegible]	[illegible]	10	62.6	20	64.4
" "	" "	2	[illegible]	[illegible]	12	61.7	25	61.7
"	" "	4	[illegible]	[illegible]	150	56.3	220	56.3
" "	" "	[illegible]	[illegible]	[illegible]	[illegible]	56.3	400	56.3
	" "	8	[illegible]	[illegible]	[illegible]	55.4	440	55.4
[illegible]	" "	[illegible]	[illegible]	[illegible]	[illegible]	54.4	[illegible]	63.5
" "	" "	2	[illegible]	[illegible]	[illegible]	56.1	150	56.1
	" "	4	[illegible]	[illegible]	[illegible]	55.4	300	56.3
	" "	[illegible]	[illegible]	[illegible]	[illegible]	55.4	550	55.0
	" "	8	[illegible]	[illegible]	[illegible]	54.6	900	55.0
[illegible]	" "	[illegible]	[illegible]	[illegible]	[illegible]	......	100	......
		2	[illegible]	[illegible]	[illegible]		[illegible]	....
		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	....
		[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	......
		8	[illegible]	[illegible]	[illegible]	.	[illegible]	......
	[illegible]	[illegible]	[illegible]		[illegible]	..	[illegible]	......
[illegible]		[illegible]	[illegible]		[illegible]	... .	[illegible]	......
[illegible]		[illegible]	[illegible]		[illegible]		[illegible]	......
[illegible]			[illegible]		[illegible]	----	[illegible]	......
[illegible]		[illegible]	[illegible]			..	[illegible]	.....
	" "	[illegible]	[illegible]		.	.. ..	[illegible]	......
	" "	[illegible]	[illegible]			..	[illegible]	......
[illegible]	[illegible]	[illegible]	[illegible]			...	[illegible]	....
[illegible]	[illegible]	8	[illegible]			.....	225	......

[illegible]

As a matter of record, the average monthly temperatures of the

nd those of the water, both as pumped from the river, and also storage for nominal periods of 24, 48 and 72 hours, respectively, iven in the following table:

TABLE No. XXXVIII.

Showing Monthly Average of Temperature Observations.
Degrees Centigrade.

MONTH, 1901.	Air.	River Water Before and After Subsidence.			
		Before.	After 24 hours.	After 48 hours.	After 72 hours.
ry..	12.4	8.8	9.0	9.3	9.5
ary . ..	11.4	8.1	8.4	8.8	9.3
1	15.8	10.8	11.3	11.8	12.3
	18.3	13.6	15.0	17.0	18.0
	23.2	19.6	20.7	19.6	20.0
	27.5	25.0	22.7	22.8	24.0
	28.1	29.3	29.1	29.0	28.9
st	27.7	29.7	29.3	28.9	28.5

Temperatures were observed at 8:00 A. M.

No allowance has been made for reduction of temperature by oration.

During this investigation the basins were provided with a number erflow partitions and baffles. These did not seem to be of much when marked stratification occurred, but it is believed that in ice they would be generally helpful.

In estimating the removal of suspended matter, which could be cted in practice, it is necessary to bear in mind that this investiga- was made with a river water of much less than average turbidity, hat during a large portion of the test the river water did not in such large amounts of coarser particles, which would settle dy, as would be the case in practice extending over a period of al years.

A careful investigation of the entire results obtained, and the itions relating thereto, reveals the fact that the data for the month pril are believed to be most representative of what could be ex- d in practice by plain subsidence for periods of 24, 48 and 72 s. During this period the amount and character of the suspended er in the river water, as well as the temperature of the air and r, were such that the results of subsidence would naturally be cted to be less than could be obtained as an annual average, other itions being equal. It is believed that the differences in the fac- above stated would go a long way towards offsetting the superior ts naturally obtained in the smaller basins. However, as a factor

of safety, it is estimated that the results on a large scale would show a removal of from about 3 to about 5 per cent less than those obtained during these investigations for the period between March 27 to April 15.

In the following table is given a series of 6 comparisons, showing the degree of clarification of the river water which was actually obtained during the investigations under different conditions, and also what it is estimated could be obtained in practice on an average.

TABLE No. XXXIX.

Showing the Results of Plain Subsidence, for Different Periods.

	Average Temperature.		Percentage Removals.							
	Air.	Water.	After 12 hours.		After 24 hours.		After 48 hours.		After 72 hours.	
			S. T.	S. M.	S. T.	S. M.	S. T.	S. M.	S. T.	S. M.
I.—Average of all results.....	20.3	17.6	23	31	33	43	44	57	58	71
II.—Average with largest basins, Dec. to Apr.......	14.4	10.8	...	...	22	44	32	51	51	66
III.—Average with largest basins, May to Aug..	26.3	25.1	33	49	47	...	58	60	64	79
IV.—Average with largest basins, Mch. 27 to Apr. 15	17.0	13.0	...	...	27	51	41	59	49	68
V.—Estimated for average conditions in practice...	......	......	19	33	28	45	37	54	42	59

In the above table S. T. equals Silica Turbidity; S. M. equals Suspended Matter.

With regard to the estimated removal above stated for different periods of subsidence, it is, of course, to be remembered that during the winter, and at other seasons when the river water was fairly clear, the percentages of removal would very likely be considerably less than those above stated. On the other hand, during the warmer portion of the year, and when the river water was more turbid, materially better results would be obtained. In other words, markedly turbid water would settle more rapidly than is indicated in the above table.

AVERAGE AMOUNT OF SILICA TURBIDITY AND SUSPENDED MATTER REMAINING IN THE MISSISSIPPI RIVER WATER AFTER VARIOUS PERIODS OF PLAIN SUBSIDENCE.

One of the principal objects of this investigation was to ascertain the economical limit of plain subsidence; that is, how long it was necessary to settle the water in order to reach a condition where further clarification could be more economically effected with the aid of a coagulant. This obviously involves a consideration of the turbidity remaining in the water after its having been settled for various periods, as well as the amounts of coagulant necessary for treatment of waters of different turbidity. The latter point is considered in subsequent chapters, but the former as a matter of convenience for reference

given in the following table, based upon the foregoing percentages removal for a river water of average composition.

TABLE No. XL.

lowing Estimated Amounts of Silica Turbidity and Suspended Matter Remaining in the Normal River Water for Different Periods of Plain Subsidence.

Hours.	Percentage Removed.		Parts per Million.		Turbidity Co-efficient.
	Silica Turbidity.	Suspended Matter.	Silica Turbidity.	Suspended Matter.	
0	0	0	600	650	1.08
12	19	33	485	435	0.90
24	28	45	430	360	0.85
48	87	54	380	300	0.80
72	42	59	350	265	0.76

DISPOSAL OF SEDIMENT ACCUMULATED BY PLAIN SUBSIDENCE.

Much information regarding the amounts of suspended matter ich would be deposited in the subsiding basins may be gathered m the foregoing table, and is tabulated along with other data in the lowing one. The additional data used in the preparation of this le are as follows:

Average Specific Gravity of Mud......................1.3
Weight per cubic foot.......................................81 pounds
Weight per cubic yard...................................1.09 tons

These figures are the average results of actual determinations of weights of dried matter contained in given volumes of mud.

TABLE No. XLI.

owing Estimated Amounts of Suspended Matter Which Would Be Deposited from the Mississippi River Water.

eriod of Sub-dence.	Suspended Matter. Parts per Million.	Mud to be Removed.			
		Per Million Gallons.		Per Annum.	
		Cubic Yards.	Tons.	Cubic Yards.	Tons.
12	215	2.28	2.48	33,300	36,200
24	290	3.07	3.35	44,800	48,900
48	350	3.71	4.05	54,100	59,100
72	385	4.08	4.45	59,500	65,000

The amount of mud to be removed from both subsiding and gulating basins amounts to 6.92 tons, or 6.35 cubic yards per million

gallons, or, in other words, 101,000 tons, or 92,700 cubic yards per annum for a supply of 40 million gallons daily capacity. This computation assumes that the effluent of the basins would contain 50 parts of suspended matter per million.

CHARACTER OF THE ACCUMULATED SEDIMENT.

The accumulated sediment varied in consistency from a thin to a thick fluid, becoming more compact as the bottom of the layer was reached. The sediment, however, did not become compact enough in four months to prevent its being easily washed out with a hose. Much of it, in fact, flowed out through the 2.5-inch washout pipe of its own accord.

There were some evidences of decomposition of organic matter which were noticed when the basin was cleaned and the bottom portion of the sediment layer was found to be considerably blackened by the formation of sulphides, through the action of hydrogen sulphide, formed during the decomposition, upon the iron contained in the sediment.

The sediment was distributed in a level layer over the floor of the basin, a further indication of its fluidity and the stratification of the suspended matters. In practice, where the bottom of the basin would be sloped, this sediment could be readily removed by draining and flushing the sediment into convenient channels and sumps by means of squilgees and a hose stream, or the sediment could perhaps be more conveniently removed without draining the basin by means of a hydraulic dredge. If the basins are cleaned as often as once in four months, satisfactory conditions of operation, from a sanitary standpoint, would surely be obtained. On the other hand, this period between cleanings could undoubtedly be considerably prolonged. It is believed that the character of the particles contained in the local river water would probably decrease the difficulties which are usually connected with the removal of the accumulated sediment from the basins in some other cities, because it is believed that very compact accumulations of sediment would not normally exist under local conditions.

When the basins were first put into operation, a quantity of corn meal was used to stop the leaks which existed at that time. This probably furnished food for decomposition, and may explain the growths of bacteria which occurred in the basins, as are described below.

GROWTHS OF ALGÆ IN THE BASINS.

During the late Spring and Summer growths of algæ attached themselves to the walls and braces of the wooden basins. Some of these masses became detached, and after floating upon the surface of the water for some time, sank to the bottom. These growths were not serious, and in the writer's opinion would not be so likely to occur upon

the masonry walls of a large basin as upon the wooden walls of the small basins used during these investigations. The algæ, however, which sank to the bottom, increased the amount of organic matter in the accumulated sediment and, therefore, the decomposition of the same.

In practice each basin would be provided with by-passes. This would permit one to put any basin out of service at will; especially during periods of low turbidity when a small portion of the basin capacity would be sufficient for the proper treatment of the water. These growths of algæ would occur during periods of low turbidity because the amounts of sediment carried in the water at other times would prevent the passage of light into the water. Algæ do not grow in water except under the influence of light.

THE REMOVAL OF BACTERIA BY PLAIN SUBSIDENCE.

It will be seen, upon inspecting the tables showing the number of bacteria in the Mississippi River water before and after plain subsidence, that the efficiencies of the basins in this particular were very low, and at times the numbers of bacteria in the basin effluent exceeded those in the river water.

Growths occurred from time to time in the basins and consisted largely of one or two species of liquefying bacteria. It is impossible, however, to attach much importance to these growths if the wooden construction of the basins, the use of corn meal to tighten the same, and the low numbers of bacteria in the river water are taken into account.

The tables also show that better percentage removals of bacteria were obtained after the water had been subsided for short periods than after long periods. This fact is brought out very clearly in the following table, which gives the average bacterial efficiencies of the various basins during the whole time of the investigation.

TABLE No. XLII.

Showing the Numbers of Bacteria in the Influents and Effluents of the Various Subsiding Basins, the Bacterial Efficiency of the Same, and the Lengths of the Periods of Subsidence

Basin No.	Hours.	Average Bacteria per Cubic Centimeter.		Bacterial Efficiency.
		Influent.	Effluent.	
1	72	2,000	3,900	— 95 per cent.
2	48	2,200	5,500	—150 " "
3	12	1,900	1 300	+ 32 " "
3	48	2,000	2,300	— 15 " "
4	12	1,900	1,300	+ 32 " "
4	24	2,200	1,900	+ 14 " "

CHAPTER IV.

Description and Results of the Operation of the English Filter No. 1, and Discussion of the Leading Features Associated Therewith.

The operation of Subsiding Basin No. 1, supplying settled water to the English Filter No. 1, was described in the preceding chapter. It remains to describe the operation of the filter and to give the results obtained from it.

As described in Chapter II, Filter No. 1 had a 4.5 foot layer of fine sifted sand (effective size 0.21 m. m.). It received Mississippi River water after three days of plain subsidence, and was operated at a rate of 2.6 millions gallons per acre daily.

DESCRIPTION OF THE REGULAR OPERATION OF FILTER NO. 1.

Continuous Plan.—The filter was operated on the continuous plan, a water depth of four feet or more being maintained above the sand surface. The water level in the basin and filter was practically the same, and the pipes connecting the basins and filters were kept wide open.

Regulation of the Rates.—The rate of filtration was regulated by a valve placed in the outlet pipe between the filter and the meter. By this means the rate was satisfactorily adjusted as required.

Loss of Head.—The loss of head was read thrice daily, a few minutes after adjusting the rate of filtration.

Collection of Samples.—Samples of the filter effluent were collected three times daily for bacterial analysis and turbidity determination, on the 8th, 16th and 24th hours, and each week an average daily sample was collected for chemical analysis.

Head Utilized.—As a rule the filter was permitted to run until the loss of head reached four feet, the initial depth of the water above the sand layer. In one or two cases, however, the loss of head was permitted to exceed the depth of water above the sand layer.

Scraping.—When the loss of head equalled four feet, the filter was drained and scraped. When it was decided to scrape the filter, the inlet pipe was closed and the filter was allowed to drain out at the usual rate until the water level was about 1.0 foot below the surface of the sand. Boards were then put upon the surface of the sand and

about 1.0 inch of the latter was removed by scraping with a square edged shovel. The sand was removed and replaced as is described below.

Depth of Scraping.—Usually 1.0 inch in depth of sand was removed. This did not remove all the discolored layer. The quantities of sand which were removed by scraping were measured with suitable appliances after their removal from the filter.

Filling from Below.—After scraping, the filter was refilled from below, with filtered water, through the outlet pipe, at a rate equal to that employed during filtration. This procedure was executed without difficulty; the rising water effectually driving the air before it. When the water had risen far enough above the sand layer to prevent the disturbance of the latter by the inflowing water, the influent valve was opened and the filter was allowed to fill up to the normal water level, this being practically the same in both basin and filter.

Resumption of Filtration.—When the filter was filled, the outlet was opened and filtration was begun at the prescribed rate. Special bacterial and turbidity samples were taken at specified intervals, beginning immediately after the resumption of filtration. When the filter was first put in operation, December 15, the rate was reduced to 1.3 million gallons per acre per 24 hours until January 8. At all other times, however, filtration was resumed at the full rate immediately after scraping. It is not believed that this practice materially affected the results of operation.

Initial Data.—The following data are grouped below for convenient reference:

		Filter No. 1.
Diameter, feet		16.0
Area, square feet		199.0
Area, acres		0.00458
Depth of gravel, inches		7.0
Number of layers of gravel		5.0
Effective size of sand, millimeters		0.21
Uniformity co-efficient of sand		1.57
Rate	Vertical millimeters per hour	100.
	Vertical feet per day	8.
	Million gallons per acre per 24 hours	2.56
Total utilized head, feet		4.0
Total gallons per day		12,000.
Total period of subsidence, days		3.
Total period of plain subsidence, days		3.
Period of coagulation, days		0.

The significant data derived from the results of operation of this filter are tabulated beyond. The headings used in these tables are self-explanatory, with the exceptions noted below:

Period.—The period of operation includes all of the operations of the filter from the time the outlet is first opened following scraping until it is again opened after the next scraping, the time of opening the outlet being taken as the date of the beginning of filtration for the next period.

Hour.—All times in this report are expressed on a 24-hour day basis, the 24th hour being midnight.

Silica Turbidity.—The abbreviation " S. B." refers to the effluent of the subsiding basin. On the average, the turbidity co-efficients of the influent and effluent of this filter are 0.76 and 0.50, respectively, and these figures are used uniformly throughout the table.

Special Samples after Scraping.—In Table No. XLIII are given the results of special bacterial analyses of the filtered water to learn the effect of scraping, and the averages of regular bacterial analyses of the effluent, of the date of scraping and for the two days before and after scraping, are also given for the sake of comparison. These samples were taken at regular intervals after opening the outlet, and correspond to quantities of effluent and periods of time after resuming filtration as follows:

Quantities Passed, Filter No. 1.		Elapsed Time.
Million Gallons per acre.	Vertical Millimeters.	Hours.
0.05	50	0.5
0.11	100	1.0
0.21	200	2.0
0.35	300	3.0
0.43	400	4.0
0.54	600	6.0

Chemical Analyses of the effluent are given in Chapter VIII.

TABLE XLIII.

Showing Results of Bacterial Analyses of Effluents of Filter No. 1, to Show Effect of Scraping.

Date of Scraping, 1901.	Bacteria per Cubic Centimeter. Average Results on Regular Samples on Days Preceding Scraping. Second.	First.	Special Results after Passage of Stated Quantities of Effluent, in Million Gallons per Acre after Scraping. 1.28	2.57	5.15	7.70	10.30	15.30	Average.	Average Results of Regular Samples taken on Day of Scraping.	First Day after Scraping.	Second Day after Scraping.
Jan. 31......	550	500	400	375	300	325	500	....	380	675	3,000	4,300
Feb. 24......	.....	1,900	2,500	5,300	750	250	1,200	....	2,000	....	625	1,100
Mar. 16......	625	475	850	1,200	......	800	550	....	850	....	....	500
Apr. 6......	100	90	350	475	5,300	150	190	300	1,125	240	130	100
" 26......	850	....	800	2,000	700	425	1,900	1,400	1,200	....	1,000	700
May 11......	100	....	600	300	1,700	550	650	325	700	....	180	140
" 23......	475	....	1,400	375	110	....	....	700	650	....	150	40
June 4......	41	....	....	.....	....	....	....	....	....	....	120	130
" 13......	55	60	450	120	150	75	....	80	175	....	55	55
" 21......	75	110	750	425	100	65	130	170	275	....	180	....
July 2......	50	48	160	220	80	55	55	800	230	....	55	46
" 27......	55	45	110	30	22	26	55	275	85	....	230	95

TABLE XLIV.

Showing Leading Qualitative Results of Operation of System No. 1, Arranged by Periods.

Number of Period.	Began Date.	Hour.	Temperature of Effluent. Deg. C.	Silica Turbidity. Subsiding Basin.	Effluent.	Bacteria. River.	Subsiding Basin.	Effluent.	Bacterial Efficiency. Filter.	System.
1	Dec. 17, 1900	9:00	10.5	120	40	1,500	19,000	6,200	67.4	......
2	Jan. 31, 1901	3:00	10.3	130	26	2,700	12,000	2,200	81.7	18.5
3	Feb. 24, "	6:00	9.1	110	18	1,900	3,400	340	90.0	82.1
4	Mar. 17, "	13:10	13.5	170	17	2,700	3,800	340	91.1	87.4
5	Apr. 6, "	20:00	15.6	320	23	2,600	9,500	270	97.3	89.4
6	" 26, "	11:00	20.5	270	15	2,900	4.400	330	92.5	88.6
7	May 11, "	19:00	22.5	155	13	2.400	950	170	82.1	92.9
8	" 23, "	21:00	22.8	85	8	1 600	1,300	55	95.8	96.6
9	June 4, "	16:00	25.7	85	4	2,700	950	80	91.6	97.0
10	" 13, "	20:00	27.0	110	1	2,100	650	70	89.2	96.7
11	" 21, "	23:00	28.1	125	1	1,500	460	60	87.0	96.0
12	July 2, "	23:00	28.8	150	1	1,700	790	45	94.3	97.3

TABLE No. XLV.

Sumary of Quantitative Results of Operation of Filter No. 1. Arranged by Periods.

Operation.									Sand Removed.					
										Amount Removed in Cubic Yards.				
Number of Period.	Date Began, 1900-1901.	Date Ended, 1901.	Period of Service, Days.	Total Quantity of Water Filtered Gallons.	Average Silica Turbidity $S.B_1$. Parts per Million.	Average Suspended Matter $S.B_1$. Parts per Million.	Millon Gallons per Acre.	Average Gross Rate. Million Gallons per Acre per 24 Hours.	Depth in Inches.	Actual.	Per Million Gallons Effluent.	Per Acre of Surface.	Per Ton of Applied Suspended Matter.	Number of Period.
1	Dec. 17, 9:00	Jan. 28, 23:00	42.64	341,352	120	85	74.5	1.75	.71	.436	1.30	95	3.60	1
2	Jan. 31, 3:00	Feb. 21, 15:00	21.50	237,953	130	95	51.9	2.40	.28	.172	.72	38	1.83	2
3	Feb. 24. 6:00	Mar. 9, 18:55	13.54	145,879	110	90	31.8	2.29	1.36	.840	5.75	184	15.40	3
4	Mar. 17, 13:10	Apr. 5, 17:00	19.16	209,455	170	115	45.7	2.39	1.21	.745	3.55	163	7.42	4
5	Apr. 6. 20:00	" 25, 4:00	14.33	163,533	320	235	35.7	2.38	.82	.500	3.05	109	3.12	5
6	" 26, 11:00	May 10, 5:00	13.75	149,735	270	215	32.7	2.37	.97	.600	4.00	130	4.45	6
7	May 11, 19:00	" 20, 17:00	8.92	87,580	155	125	12.2	2.13	.90	.552	6:30	121	10.10	7
8	" 23, 21:00	June 2, 7:00	9.42	90,320	85	80	12.8	2.06	.89	.550	6.10	120	18.3	8
9	June 4, 16:00	" 12, 10:00	7.75	76,390	85	80	16.7	2.11	.78	.480	6.30	105	18.9	9
10	" 13, 20:00	" 19, 22:00	6.08	61,500	110	75	13.5	2.02	.89	.550	8.95	120	28.6	10
11	" 21, 23:00	" 30, 18:50	8.83	84,663	125	90	18.5	2.10	.97	.600	7.10	131	18.9	11
12	July 2, 23:00	July 13, 20:20	10.89	105,823	150	105	23.1	2.16	.95	.590	5.55	129	12.8	12

SIGNIFICANT RESULTS OF OPERATION OF FILTER NO. 1.

In addition to the data noted in the foregoing tables, it may be stated that the precautions taken to prevent percolation of water along the walls of the filter without passing through the sand were adequate; as no increased discolorization of the sides of the sand layer could be noted such as would be indicative of unequal rates.

A few small fishes, weavils and shrimp found their way on to the filter, but did not seriously disturb the sand layer.

On one occasion it was attempted to operate the filter with a negative head, but the loss of head increased from 4 to 9 feet within 48 hours, showing the impracticability of this procedure under the existing local conditions.

The leading results of operation confirm the conclusions of other investigations with this general type of water, bringing out still more clearly the following points:

The Mississippi River water, after having been settled for 72 hours, is characterized by the absence of organic matter capable of forming gelatinous films on the sand, and by the presence of large numbers of very fine particles of clay. These clay particles themselves are somewhat gelatinous in their nature, and act within certain limits as a substitute for film-forming organic matter. These clay particles are sub-microscopic in size—many of them less than 0.00001 inch—0.0002 millimeter—and, when present in numbers exceeding a certain limit, penetrate deeply into the sand layer. Under these circumstances the operation of the filter, if long continued, may be seriously interfered with, and the removal of bacteria, as well as of the clay particles, may become unsatisfactory.

The extent of the penetration of clay particles and of organic matter is shown in the following table:

TABLE XLVI.

Showing Penetration of Clay, etc., into the Sand Layer of Filter Number 1.

Date, 1901.	Depth.	Parts per Million.			
		Clay.	Iron Oxid.	Alumina.	Albuminoid Ammonia.
....	New Sand...	1,600	....	....	5.75
Jan. 29.	Surface.......	36,000	....	....	300.0
" 29...........	1 inch...	29,000	....	....	25.0
" 29...........	3 "	8,500	....	....	10.0
" 29...........	6 "	4,500	....	....	7.0
Mar. 11...........	Surface.......	17,500	....	....	53.0
" 11......	½ inch........	9,000	....	....	39.0
June 20	Surface.......	45,000	1,070	2 640	88.0
" 20...........	2 inches......	15,000	935	1,820	26.8
" 20......	4 "	14,000	550	960	22.6
" 20	6 "	10,000	160	390	7.75
July 5.............	Surface.......	....	....	....	210.0
" 5.............	1 inch.........	....	....	....	33.5
" 5.............	2 "	....	....	....	16.5
" 5.......	3 "	....	....	....	14.75
" 5..	4 "	....	....	....	8 05
" 5.............	6 "	....	....	....	7.35
Aug. 19...........	Surface.......	10,000	....	....	67.0
" 19...........	3 inches......	1,000	....	....	11.5
" 19...........	6 "	800	....	....	12.0
" 19	1 foot......	800	....	....	12.5
" 19...........	2 feet	725	....	....	12.5
" 19	2.25 "	700	....	....	12.0

The amounts of these fine clay particles which remained in the water after plain subsidence for 72 hours were unusually large, compared with conditions elsewhere. The monthly averages of the amounts of suspended matter which may remain in the water of a normal year after three days' plain subsidence may be given as follows:

MONTH.	PARTS PER MILLION.	
	Silica Turbidity.	Suspended Matter.
January	200	150
February	350	265
March	600	460
April	775	590
May	750	575
June	500	385
July	300	225
August	210	160
September	170	125
October	120	90
November	90	70
December	120	90
Average	350	265

During the latter part of this investigation—summer weather—it was found that the filter produced an effluent of satisfactory character when the turbidity of the influent did not exceed 150 parts, silica standard, or 120 parts of suspended matter. With a well-ripened filter, constructed and operated under these conditions, it is very doubtful whether a satisfactory effluent could be obtained at all times with an effluent as turbid as stated above. General experience certainly indicates that this would not always be the case.

Comparing the amounts of turbidity found in the river water after subsidence for 72 hours during each month of a normal year, with the permissible limits stated in the last paragraph, it is found that this limit would be exceeded during eight months of the year. During some years this period of unsatisfactory operation would, of course, be longer, and during other years it would be shorter than for the average year above mentioned. In other words, for about two-thirds of the time plain subsidence of the Mississippi River water for 72 hours would not prepare the water so that an English filter could treat it satisfactorily under the stated conditions of construction and rate of filtration. Furthermore, this situation could not be relieved by reducing the rate of filtration within any practicable limits.

Double filtration of the subsided water has been employed at Bremen and Altona, Germany, with satisfactory results. The amounts.

of suspended matter in the local water are so high, however, that at certain seasons of the year the effluent of the primary filter would be too turbid to be satisfactorily treated by the secondary filter.

As to the cost of operation of the method under consideration, it is to be stated that the amount of clogged material to be removed from the filter by scraping would range from three to six times that ordinarily experienced in practice elsewhere, notwithstanding the unsatisfactory quality of the effluent for more than one-half the time.

Obviously, in order to obtain a satisfactory and economical effluent, it is necessary to avoid this excessive cost of operation of the filter, and to provide for further and adequate preliminary treatment of the river water. Therefore, it is needless to consider further this system, which, as is well known, comprises only plain subsidence followed by filtration through an English filter.

CHAPTER V.

DESCRIPTION OF THE OPERATION OF THE MODIFIED ENGLISH SYSTEM OF WATER PURIFICATION, AND DISCUSSION OF THE LEADING FACTORS ASSOCIATED THEREWITH.

The distinguishing feature of this system as compared with System No. 1, consists in the more complete preparation of plain subsided water before filtration, thus providing water of such slight turbidity that the filter cannot only produce an effluent of satisfactory character but also can be operated at a rate considerably higher than that employed in the case of Filter No. 1. This further clarification is effected with the aid of coagulant used in connection with a supplementary subsiding basin, called a coagulating basin. It cannot be effected practically by double filtration without coagulant.

The main features of this system, together with the various initial data, are tabulated below for convenient reference.

		Filter No. 2.
Diameter, feet		9.8
Area, square feet		75.3
Area, acres		0.00173
Depth of gravel, inches		7.0
Number of layers of gravel		5.
Effective size of sand, millimeters		0.385
Uniformity co-efficient of sand		1.48
Rate	Vertical millimeters per hour	200.
	Vertical feet per day	16.
	Million gallons per acre per 24 hours	5.2
Total utilized head, feet		4.0
Total gallons per day		9,000.
Total period of subsidence, days		3.
Period of plain subsidence, days		2.
Period of coagulation, days		1.

Investigations made at other places indicated that it was advisable to arrange and operate the coagulating basin so that the water reaching the filter should not contain more than from 30 to 50 parts of suspended matter per million, probably less, and that when this was done the filter could be satisfactorily operated under local conditions, at double the German standard rate—5.2 million gallons per acre daily. Further,

it has been learned elsewhere that a coagulating basin should contain about 24 hours flow, and that various waters of given turbidities require various amounts of coagulant for their successful treatment, depending largely upon the nature of the suspended particles producing the turbidity.

The principal object of this portion of the investigations was to ascertain the practicability—under local conditions—of the several points just stated, and especially to determine the amount of coagulant which would be required for the successful treatment of the water with various degrees of turbidity.

OPERATION OF COAGULATING BASIN NO. 2.

This basin, as is described in Chapter II, provided a normal period of coagulation of 24 hours. The water, which up to June 6th had been subsided for 48 hours, and which after June 6th was received directly from the river, was treated with sulphate of alumina as it entered at one end of the basin. It then passed through the basin and overflowed at the outlet end into a chamber which in turn was connected with Filter No. 2, as is described in Chapter II.

OPERATION BEGAN.

The basin was put into operation on December 15th, and operated continuously until July 27th, except between April 12th and 22nd, when it was stopped for cleaning and to put baffles into Subsiding Basin No. 2.

OPERATION WITH UNSUBSIDED RIVER WATER.

On June 6th Subsiding Basin No. 2 was put out of service and the river water was supplied directly to the coagulating basin. This procedure was for the purpose of collecting data regarding the feasibility and economy of adding the coagulant directly to the river water, thus omitting plain subsidence as a preliminary treatment.

COAGULATION.

Almost without exception during these investigations it was necessary to add a coagulant to the water to assist in its clarification and purification.

CHEMICAL USED AS COAGULANT.

Sulphate of Alumina was used uniformly as a coagulating chemical, not because it was the only one which could be used, but because it was the best purchasable chemical, all things considered, for the purpose of determinating the behavior of the local water. Other chemicals, such as compounds of iron, could have been used, but they

would have caused the results of coagulation to be expressed in terms less directly comparable with the results of similar experience elsewhere than was considered desirable. A plant in practice, designed to use sulphate of alumina as a coagulant could also be arranged to use other chemicals, if the same should prove advantageous.

One brand of sulphate of alumina was used, having the following percentage composition:

PERCENTAGE COMPOSITION OF SULPHATE OF ALUMINA.

Insoluble in water	0.62
Available Alumina—Al_2O_3	18.80
Sulphuric Acid—SO_3	38.24
Water—H_2O	42.30
Iron Oxide—Fe_2O_3	0.04
	100.00

This sulphate of alumina was basic; no free sulphuric acid being present.

There are sulphates of alumina on the market which contain as high as 23 per cent of alumina—the active constituent. The use of these strong salts is advisable only when the pro rata cost of the alumina is decreased thereby. A saving in the freight charges might be effected by using the stronger salt.

ACTION WHEN APPLIED TO WATER.

Alum has been used for so many years to clarify muddy water, especially here in New Orleans, and the action of the cheaper and stronger sulphate of alumina has been so accurately described in other reports and in text books, that it seems almost superfluous to repeat the description here. However, it seems best to review the main points briefly.

When sulphate of alumina is added to river water, the bases of the alkaline constituents (calcium and magnesium) immediately unite with the acid contained in the sulphate of alumina, thereby setting free the carbon dioxide (carbonic acid) which was combined with the alkaline bases, and also setting free the aluminum hydrate which was combined with the sulphuric acid. The carbon dioxide is absorbed by the water, and the aluminum hydrate, which is insoluble, remains to coagulate the suspended matters. The net result of the action of the coagulant, then, is to set free carbon dioxide; to reduce the amount of carbonates; to increase the amount of sulphates; and to precipitate aluminum hydrate, all in due proportion.

Some of the sulphate of alumina does not react with the alkaline constituents of the water but becomes absorbed directly by the suspended matter. The degree of this absorption varies greatly with the amount and character of the suspended matters, as is shown in Chapter I, page 36.

The hydrate which is precipitated is the principal agent in securing coagulation. The freshly precipitated hydrate, which has a gelatinous appearance not unlike coagulated egg-white, unites with the clay particles and brings them together into bunches or aggregates. Some of these aggregates are so large that they are plainly visible. The suspended matter in the water, after adequate treatment with a coagulant, as compared with its original condition, subsides much more readily.

Sulphate of alumina can be safely used up to the limit of the alkalinity (dissolved carbonates) contained in the water; for as long as the water remains alkaline, no undecomposed sulphate of alumina can exist in the water. The results of this investigation indicate that there always will be an excess of alkalinity in the river water, and that necessary amounts of coagulant could always be used at New Orleans without the slightest trace of undecomposed chemical ever passing through the filters and appearing in the distribution system, provided reasonable care was exercised in the operation of the plant.

DESCRIPTIONS OF TABLES XLVII, XLVIII AND XLIX. SHOWING THE LEADING RESULTS OF OPERATION OF COAGULATING BASIN NO 2.

Tables XLVII and XLVIII give the daily average results of operation of Coagulating Basin No. 2, receiving subsided water and river water, respectively.

Table XLIX gives the leading monthly average results from Tables XLVII and XLVIII. Table XLIX also includes the average monthly temperatures of air and water.

TABLE XLVII.

Showing the Leading Daily Average Results of Operation of Coagulating Basin Number 2, Receiving Subsided Water.

Date. 1901.	Silica Turbidity, Parts per Million. SB$_2$	CB$_2$	Per Cent. Removed.	Bacteria. Per cub. cent. SB$_2$	CB$_2$	Bacterial Efficiency.	Coagulant Applied in Grains per Gallon.
Dec. 19.......	300	45	85	2,200	2,100	5	2.00
" 20.......	280	17	94	4,200	4,200	0	2.23
" 21.......	290	20	93	9,800	5,000	49	2.48
" 22.......	260	15	94	5,000	5,000	0	2.55
" 23.......	240	10	96	5,000	14,000	...	3.07
" 24.......	220	90	59	5,100	6,500	...	2.78
" 25.......	220	65	70	5,200	3 400	35	2.77
" 26.......	170	13	93	27,000	51,000	...	2.90
" 27.	180	21	88	16,000	13,000	19	2.44
" 28.......	90	24	73	39 000	6 500	83	2.54
" 29.......	130	13	90	10,000	10,000	0	2.65
" 30.......	130	20	85	6,200	8,500	...	2.51
" 31...	140	8	94	....	9 400	...	2.80
Jan. 1, 1901	150	4	97	70,000	475	93	2.83
" 2.......	160	45	72	2,600	2,100	19	1.83
" 3.......	140	70	50	3,100	1,800	42	1.00
" 4.......	140	95	32	1,200	1,500	...	1.21
" 5.......	150	45	70	700	....	...	0.97
" 6.......	160	75	53	300	....	...	1.19
" 7.......	150	90	40	....	3,500	...	1.02
" 8.......	140	80	43	....	4,400	. .	1.20
" 9.......	95	70	26	2,300	1,900	17	1.18
" 10.......	110	65	41	2,400	2,300	4	1.42
" 11.......	100	45	55	14,000	2,300	84	1.20
" 12.......	120	40	67	14,000	4,100	71	1.11
" 13.......	120	35	71	7,800	4,500	42	1.43
" 14.......	110	40	64	3,900	2,500	36	1.52
" 15.......	110	45	59	1,700	190	89	1.64
" 16.......	95	50	47	130	190	...	1.22
" 17.......	140	60	57	325	275	15	1.23
" 18.	160	65	59	1,400	1,100	21	1.65
" 19.......	140	80	43	1,900	1,500	21	1.70
" 20.......	130	85	65	2,000	1,700	15	1.80
" 21.......	100	110	...	2 300	2,100	9	1.52
" 22.......	100	60	40	3,100	1,600	48	1.36
" 23.......	110	100	9	2,300	900	61	1.00
" 24.......	100	90	10	1,100	550	50	1.26
" 25.......	130	70	46	800	400	50	1.50
" 26.......	120	35	71	900	200	78	1.76
" 27.......	85	35	59	450	140	69	2.50
" 28.......	120	35	71	300	25	92	2.12
" 29.......	100	35	65	300	120	60	1 87
" 30.......	110	40	64	1,000	625	38	1.68
" 31.......	160	45	72	1,700	200	88	1.60
Feb. 1.......	170	30	82	1,700	150	91	1.60
" 2.......	140	40	71	1,000	225	78	1.82
" 3.......	190	32	83	3,200	450	86	2.06
" 4.......	180	35	81	3,000	450	85	2.08
" 5.......	170	32	81	2,800	550	80	2.30
" 6.......	180	30	83	3,000	750	75	2.18
" 7.......	120	20	83	3,100	500	84	2.10

TABLE XLVII.—Continued.

Showing the Leading Daily Average Results of Operation of Coagulating Basin Number 2, Receiving Subsided Water.

Date. 1901.	Silica Turbidity, Parts per Million. SB₂	CB₂	Per Cent. Removed.	Bacteria. Per cub. cent. SB₂	CB₂	Bacterial Efficiency.	Coagulant Applied in Grains per Gallon.
Feb. 8	140	27	93	3,300	150	95	2.22
" 9	120	28	77	3,300	150	95	2.36
" 10	160	15	94	500	100	80	2.08
" 11	85	21	75	1,000	190	81	2.07
" 12	110	48	56	1,800	160	91	1.86
" 13	150	16	89	2,000	....	...	1.77
" 14	180	15	92	....	....	...	1.62
" 15	110	15	86	....	....	...	1.59
" 16	100	15	85	....	....	...	1.48
" 17	110	15	86	....	....	...	1.90
" 18	120	15	88	4,700	....	...	2.05
" 19	130	15	88	4,900	225	95	......
" 20	160	13	92	1,900	300	84	......
" 21	130	30	77	2,800	950	66	1.45
" 22	140	45	68	2,200	....	...	1.47
" 23	170	30	83	1,700	....	...	1.56
" 24	170	14	92	2,000	180	91	1.79
" 25	160	16	90	2,300	470	80	1.94
" 26	150	35	77	2,900	200	93	1.99
" 27	130	45	65	2,000	210	90	1.89
" 28	140	22	84	1,700	180	89	1.64
Mar. 1	95	17	82	1,600	150	91	1.78
" 2	85	22	74	1,100	50	95	1.81
" 3	95	19	80	1,300	110	92	1.82
" 4	95	13	86	1,000	50	95	1.65
" 5	130	15	88	650	60	91	1.49
" 6	140	16	89	800	50	94	1.46
" 7	120	17	86	650	50	92	1.89
" 8	95	18	81	400	55	86	1.90
" 9	120	12	90	425	55	87	1.79
" 10	100	13	87	600	35	94	1.63
" 11	110	15	86	425	75	82	1.73
" 12	85	20	76	550	75	86	1.69
" 13	60	26	57	1,400	160	89	1.62
" 14	100	30	70	500	370	26	1.40
" 15	100	22	78	425	140	67	1.23
" 16	80	22	72	700	140	80	1.24
" 17	80	25	69	1,400	140	90	1.19
" 18	75	15	80	2,400	180	93	1.14
" 19	70	22	69	800	170	79	1.17
" 20	70	15	79	1,700	190	89	1.16
" 21	75	11	85	2,500	370	85	1.19
" 22	70	14	80	4,200	550	87	1.35
" 23	65	15	77	10,000	490	95	1.49
" 24	40	25	38	14,000	430	96	1.51
" 25	35	28	20	10,000	340	97	1.50
" 26	160	30	81	1,300	625	52	1.36
" 27	210	25	88	3,800	400	90	1.31
" 28	210	15	93	1,200	275	77	1.87
" 29	325	20	94	2,000	110	95	2.98
" 30	280	50	82	850	110	87	2.73

TABLE XLVII.—Continued.

Showing the Leading Daily Average Results of Operation of Coagulating Basin Number 2, Receiving Subsided Water.

Date. 1901.	Silica Turbidity, Parts per Million. SB$_2$	CB$_2$	Per Cent. Removed.	Bacteria. Per cub. cent. SB$_2$	CB$_2$	Bacterial Efficiency.	Coagulant Applied in Grains per Gallon.
Mar. 31	240	50	79	1,300	140	89	2.33
Apr. 1	450	45	90	3 400	275	81	2.56
" 2	375	30	92	1,300	120	91	2.94
" 3	450	45	90	2,700	180	93	3.43
" 4	400	30	93	2,800	170	94	3.55
" 5	350	40	89	1,700	200	88	3.57
" 6	375	30	92	2,100	140	93	3.78
" 7	400	17	96	1,400	85	94	3.64
" 8	270	15	95	1,100	90	92	3.65
" 9	270	18	93	1,700	95	94	3.61
" 10	250	32	87	1,100	100	91	3.85
" 11	170	50	71	1,700	200	88	3.38
" 12	130	40	69	750	80	89	2.59
" 22	325	20	94	14,000	700	95	4.73
" 23	300	22	93	4,600	350	92	5.36
" 24	350	13	96	2,500	350	86	4.80
" 25	325	20	94	3,000	230	92	4.14
" 26	325	23	93	2,400	325	87	3.62
" 27	350	20	94	3,100	325	90	2.95
" 28	400	23	94	3,800	250	93	2.84
" 29	350	40	82	2,200	150	93	3.13
" 30	375	28	93	1,100	300	73	3.11
May 1	425	15	96	3,300	300	91	3.40
" 2	325	16	95	1,700	180	89	3.76
" 3	350	24	93	1,700	275	84	3.66
" 4	400	28	93	1,700	500	71	2.97
" 5	375	19	95	1,600	200	88	3.27
" 6	350	16	95	1,500	275	82	3.06
" 7	350	10	97	1,700	130	92	2.83
" 8	325	11	97	2,200	180	92	2.79
" 9	290	10	97	1,600	190	88	3.22
" 10	325	16	95	3,700	130	96	2.73
" 11	300	17	94	1,200	.....	...	2.67
" 12	300	18	94	1,200	.....	...	2.87
" 13	290	16	94	1,100	1,300	...	2.14
" 14	300	17	94	1,100	350	68	2.51
" 15	280	16	94	1,700	400	76	2.64
" 16	260	16	94	1,400	425	70	2.49
" 17	260	15	94	2,400	450	81	2.52
" 18	250	15	94	1,700	425	85	2.46
" 19	180	17	91	900	400	56	2.36
" 20	210	21	90	750	200	73	2.19
" 21	210	18	91	775	150	81	2.13
" 22	190	18	91	800	65	92	2.26
" 23	170	20	88	1,100	200	82	2.40
" 24	160	22	86	1,500	475	68	1.56
" 25	150	28	81	1,900	180	91	1.72
" 26	160	35	78	1,600	650	59	1.80
" 27	160	24	85	1,700	375	78	1.93
" 28	170	40	76	1,400	350	75	1.88
" 29	170	20	88	1,300	350	73	1.94

TABLE XLVII.—Continued.

Showing the Leading Daily Average Results of Operation of Coagulating Basin Number 2, Receiving Subsided Water.

Date. 1901.	Silica Turbidity, Parts per Million. SB₂	CB₂	Per Cent. Removed.	Bacteria. Per cub. cent. SB₂	CB₂	Bacterial Efficiency.	Coagulant Applied in Grains per Gallon.
May 30.......	180	23	87	800	800	63	1.92
" 31.......	160	30	81	475	800	37	2.06
June 1.......	160	30	81	650	300	54	2.22
" 2.......	180	20	89	500	425	15	2.01
" 3.......	170	20	88	900	300	67	2.13
" 4.......	150	18	88	....	600	...	2.51
" 5.......	170	17	90	....	900	...	......
" 6.......	.....	15	...	....	....	...	......

TABLE XLVIII.

*'he Leading Daily Average Results of Operation·of Coagulat-
· Basin Number 2, Receiving Unsubsided River Water.*

	Silica Turbidity, Parts per Million.			Bacteria.			Coagulant Applied in Grains per Gallon.
				Per cub. cent.		Bacterial Efficiency.	
	River.	CB_2	Per Cent. Removed.	River.	CB_2		
...	525	27	95	3,000	1,000	67	4.02
...	500	25	95	2 800	525	81	3.93
...	500	30	94	3,300	300	91	3.76
...	425	22	95	2,100	250	88	3.91
...	500	25	95	2,800	300	89	3.86
...	450	20	96	3,100	300	90	3.45
...	400	26	94	2,200	300	86	3.76
...	450	28	94	1 400	240	83	3.65
...	475	30	94	1,200	250	79	3.70
...	450	40	91	1,600	110	93	3.96
...	450	32	93	1,000	220	78	3.98
..	400	28	93	800	190	76	4.38
...	350	23	93	1,200	250	79	3.77
...	350	20	94	1,300	190	85	3.62
...	400	25	94	950	170	82	3.58
...	400	15	96	1,200	150	88	3.90
.	375	15	96	1,600	130	92	3.90
...	400	20	95	2,000	650	68	......
...	400	35	91	2,400	700	71	3.49
...	450	43	90	2,200	750	66	3.60
...	475	38	92	2,100	500	76	4.07
...	550	30	95	2,000	250	88	4.85
...	475	30	94	1,400	300	79	4.40
...	450	35	92	1,400	190	86	4.02
...	450	35	92	1,100	170	85	4.00
...	500	37	93	2,600	375	86	3.95
...	550	45	92	1,500	350	77	4.52
...	450	45	90	1,600	250	84	4.50
...	450	45	90	1,800	160	91	4.38
...	500	45	91	1,600	190	88	4.40
...	575	40	93	2,000	110	95	4.70
...	550	45	92	1,000	220	78	......
...	650	50	92	2 000	170	92	......
...	675	50	93	1,900	110	94	......
...	725	50	93	1,600	80	95	......
...	700	40	92	1,600	750	53	7.20
...	725	35	95	1,600	90	94	7.10
...	725	32	96	1,600	100	94	7.75
...	700	32	95	1,300	120	91	8.75
...	700	35	95	3,300	90	97	8.69
...	775	35	96	1,400	600	57	8.70
...	750	35	96	2,400	200	92	8.42
...	675	50	93	2,200	275	88	9.94
...	550	50	91	2,200	250	89	9.21
...	475	45	90	1,500	250	83	7.67
..	450	23	95	1,400	275	81	6.85
...	350	25	93	2,500	275	89	6.62
...	325	27	92	2,100	500	76	5.27
...	325	22	93	1,400	375	73	4.04
...	400	16	96	4,100	120	97	3.95
...	350	10	97	1,000	100	90	3.71
...	250	5	99	1,800	300	83	......

TABLE XLIX.

Showing the Monthly Average Results of Operation of Coagulating Basin Number 2.

A.—WITH SUBSIDED WATER.

Month.	Silica Turbidity. Parts per Million.			Suspended Matter. Parts per Million.			Bacteria, per Cubic Centimeter.			Temperature, Degrees—C.			Coagulant Applied in Grains per Gallon.
	SB_2	CB_2	Per Cent. Removed.	SB_2	CB_2	Per Cent. Removed.	SB_2	CB_2	Bacterial Efficiency.	Air.	SB_2	CB_2	
Dec., 1900...	200	28	86	160	17	89	11,000	10,000	5	14.3	......	......	2.59
Jan., 1901...	120	50	58	95	30	69	5,000	1,500	70	12.4	......	9.7	1.54
Feb., " ...	150	24	84	115	14	88	2,450	325	87	11.4	......	9.1	1.88
Mar., " ...	120	21	82	95	13	86	2.250	200	91	15.8	......	13.3	1.66
Apr., " ...	325	29	91	250	17	93	2,800	225	92	18.3	17.6	17.9	3.58
May " ...	250	20	92	195	12	94	1,500	350	77	23.2	19.3	20.5	2.48

B.—WITH MISSISSIPPI RIVER WATER.

Month. 1901.	Silica Turbidity. Parts per Million.			Suspended Matter. Parts per Million.			Bacteria, per Cubic Centimeter.			Temperature, Degrees—C.			Coagulant Applied in Grains per Gallon.
	River.	CB_2	Per Cent. Removed.	River.	CB_2	Per Cent. Removed.	River.	CB_2	Bacterial Efficiency.	Air.	River.	CB_2	
June..........	440	28	94	475	17	96	1,850	325	82	27.5	25.0	23.3	3.74
July............	550	36	93	595	22	96	1,850	250	87	28.1	29.3	25.6	7.22

RESULTS OF OPERATION OF FILTER NO. 2.

This filter, receiving the effluent of Coagulating Basin No. 2, was operated in a manner similar to Filter No. 1, as described at the beginning of Chapter IV. The only differences of importance were that Filter No. 2 operated at double the rate of Filter No. 1, or at the rate of 5.2 million gallons per acre per 24 hours, and that it contained a thinner bed of coarser sand, namely, of an effective size of 0.38 m. m.

When the system was first put into operation, the coagulating basin was covered with an open sided shed roof as is described in Chapter II. This cover, however, was removed during the last part of April in order to observe the effect of algæ growths upon the operation of both basin and filter. On May 12th the filter was covered with boards

which were removed on May 13th and replaced on May 24th. This was to study the effect which the exclusion of the light would have on the growths of algæ in the water and upon the surface of the sand layer. During the time the cover was removed, between May 13th and 24th, the period of service was markedly reduced, but when the cover was replaced the algæ growths on the surface of the sand were diminished and the period of service was considerably lengthened.

In the following tables, L, LI and LII, are shown the leading results of operation of the filter. The data are arranged in a manner similar to those given for Filter No. 1 in the preceding chapter, and here it is only necessary to note the plan of taking special bacterial samples after scraping, as shown in Table LII. These special samples were taken at 0.25, 0.5, 1.0, 1.5, 2.0, 3.0 hours after opening the outlet.

The chemical analyses of the effluent are given in the Chapter VIII. It may be noted here that the effluent of this filter was uniformly free from turbidity.

TABLE L.

Showing Leading Qualitative Results of Operation of System Number 2, Arranged by Periods.

Number of Period.	Began.		Temperature of Effluent, Degrees—C.	Average Amount of Coagulant in Grains per Gallon.	Silica Turbidity.		Bacteria.				Bacterial Efficiency.	
	Date.	Hour.			SB_2	CB_2	River.	SB_2	CB_2	Effluent.	CB and Filter.	System.
	1900.											
1	Dec. 15...	11:35	9.0	1.73	160	44	1,850	10,800	7,100	1,900	82.4	......
	1901.											
2	Jan. 16...	21:03	9.1	1.39	120	70	525	1,600	1,100	325	79.7	38.1
3	" 23...	18:00	11.0	1.75	110	65	725	1,300	375	130	90.0	62.5
4	" 29...	22:30	9.8	2.05	145	29	2,350	2,000	425	290	85.5	87.7
5	Feb. 21...	17:00	12.3	1.58	110	21	1,650	2,800	220	31	98.9	98.1
6	Mar. 30...	21:00	14.4	3.25	305	34	4,100	1,700	140	9	99.5	99.8
7	Apr. 22...	13:15	19.6	3.42	345	19	2,800	2,900	300	26	99.1	99.1
8	May 13...	22.00	21.3	2.37	235	17	2,400	1,250	400	50	96.0	97.9
9	" 24...	21:00	22.6	1 98	165	27	1,650	1 100	350	19	98.3	98.8
10	June 7...	9:00	25.1	3.84	440	26	1,900	........*	525	27	....	98.6
11	" 25...	4:00	27.7	4.45	485	38	1,800	........*	375	23	....	98.7
12	July 12...	17:00	29.1	6.88	560	36	2,000	........*	275	14	....	99.3
13	" 29...	16:20	28.4	0.	170	80	1,600	525‡	....	43	91.8	97.3
14	Aug. 8...	19:00	28.1	0.	115	65	800	300‡	....	33	89.0	95.9

NOTE.—Period No. 14 not completed.

*River water pumped directly into CB_2.
‡Effluent of SB_1, pumped directly into Filter No. 2.

TABLE LI.

Summary of Quantitative Results of Operation of Filter Number 2, Arranged by Periods.

Number of Period.	Date and Hour Began, 1900-1901.	Date and Hour Ended, 1901.	Operation. Period of Service, Days.	Total Quantity of Water Filtered, Gallons.	Average Silica Turbidity, SB_2, Parts per Million.	Average Suspended Matter, SB_2, Parts per Million.	Average Silica Turbidity, CB_2, Parts per Million.	Average Suspended Matter, CB_2, Parts per Million.	Average Applied Coagulant in Grains per Gallon Water Filtered.	Million Gallons Water Filtered per Acre Surface.	Average Gross Rate of Filtration, Million Gallons per Acre per 24 Hours.	Sand Removed. Depth, Inches.	Amount Removed in Cubic Yards. Actual.	Per Million Gallons Effluent.	Per Acre Surface.	Per Ton of Applied Suspended Matter.
1	Dec. 15, 11:35	Jan. 16, 13:45	32.09	258,692	160	135	44	35	1.73	148	4.62	1.01	.238	.92	136	6.32
2	Jan. 16, 21:03	Jan. 23, 10:40	6.57	58,401	120	110	70	50	1.39	33	5.08	1.56	.367	6.25	210	30.10
3	Jan. 23, 18:00	Jan. 29, 9:18	5.64	47 057	110	100	65	50	1.75	27	4.77	.75	.176	3.75	100	17.95
4	Jan. 29, 22:30	Feb. 17, 7:45	18.38	167.247	145	115	29	20	2.05	95	5.16	.83	.194	1.16	111	13.90
5	Feb. 21, 17:00	Mar. 30, 2:00	36.38	328,037	110	90	21	17	1.58	188	5.11	1.17	.275	.84	157	11.85
6	Mar. 30, 21:00	Apr. 12, 23:00	13.08	122,770	305	245	34	26	3.25	70	5.37	1.37	.323	2.63	185	24.30
7	Apr. 22, 13:15	May 12, 11:00	19.91	185,520	345	255	19	18	3.42	106	5.32	1.36	.321	1.73	183	23.05
8	May 13, 22:00	May 23, 18:00	9.83	89,838	235	180	17	12	2.37	51	5.28	.97	.229	2.55	131	51.00
9	May 24, 21:00	June 4, 22:00	11.04	101,310	165	135	27	22	1.98	58	5.35	.97	.229	2.26	131	24.75
10	June 7, 9:00	June 23, 2:30	15.72	137,282	*440	*440	26	24	3.84	78	4.95	.88	.206	1.50	118	15.00
11	June 25, 4:00	July 7, 19:00	12.55	107,758	*485	*520	38	19	4.45	61	4.80	.98	.230	2.14	132	27.00
12	July 12, 17:00	July 27, 4:00	13.85	126,871	*560	*560	36	25	6.88	72	5.06	.73	.172	1.36	98	13.05
13	July 29, 16:20	Aug. 7, 10:30	9.50	85,425	*170	*120	‡80	‡55	....	48	4.90	.56	.132	1.55	75	6.75
14	Aug. 8, 19:00	Aug. 17, 24:00	8.95	84,456	*115	*75	‡65	‡45	....	......	5.39	....	....	....	....	....

Period Number 14 not completed.

*** Values are for River Water which was pumped directly to CB_2 during these periods.**
‡ Values are for SB_1 water which was pumped directly to CB_2 during these periods.

TABLE LII.

Showing Results of Bacterial Analyses of Effluent of Filter No. 2, to Show the Effect of Scraping.

BACTERIA PER CUBIC CENTIMETER.

Date of Scraping, 1901.	Average Results of Regular Samples on Days Preceding Scraping.		Special Results after Passage of Stated Quantities of Effluent in Million Gallons per Acre, after Scraping.							Average Results of Regular Samples Taken.		
	Second Day.	First Day.	1.28	2.57	5.15	7.70	10.30	15.30	Average.	Day of Scraping.	First Day after Scraping.	Second Day after Scraping.
Jan. 16	525	375	20	0	11	0	0	.....	6	17	33	24
Jan. 23	400	325	250	150	800	1,100	900	.....	650	750	225	200
Jan. 29	60	47	300	140	.....	110	130	.....	170	250	65	1,500
Feb. 21	.....	....	9,000	.....	.....	.....	.....	.....	9,000	......	65	65
Mar. 30	21	70	250	190	475	2,100	100	110	550	1,600	28	15
May 13	24	.....	1,900	900	650	180	200	130	650	43	150	95
May 24	18	16	......	220	210	140	120	130	160	33	75	24
June 7	11	95	0	0	0	0	100	200	50	110	90	40
June 25	10	11	80	18	90	48	70	80	65	70	37	24
July 12	18	24	1,400	2,000	900	.....	.....	.....	1,400	3,500	250	70
July 29	12	80	85	44	44	33	55	46	50	41	90	110
Aug. 8	85	48	85	95	75	150	65	75	90	175	95	47

LEADING FEATURES OF THE OPERATION OF THE MODIFIED ENGLISH FILTER, AND THE PRACTICAL SIGNIFICANCE OF THE RESULTS OBTAINED.

The most characteristic features of the operation of the modified English filter and their practical significance may be described as follows:

With an applied water which had a silica turbidity of not exceeding 80 parts per million (equivalent to about 50 parts per million of suspended matter) the effluent of Filter No. 2 was perfectly clear at all times, and during the summer months this turbidity of the applied water could reach 100, or even 150 parts per million for short periods without affecting the appearance of the effluent. A rate of filtration of 5.2 million gallons per acre per day was employed during this investigation and was found on the whole to be satisfactory with properly treated applied water after the filter had become sufficiently aged; this ageing of the filter required about two months.

At times, after scraping the filter, the bacterial results were somewhat abnormal for a short period. This was evidently due for the most part to growths of algæ or other bacteria in the sand layer itself. In practice this feature would be of little or no account. It is to be remembered in this connection that while gas-producing bacteria were very abundant in the influent of the filter, they were almost always absent from the effluent.

When, during the winter months, the silica turbidity of the effluent of the coagulating basin reached 70 parts per million (about 45 parts per million of suspended matter) the period between scrapings was reduced to about 6 days. equivalent to a yield of about 30 million gallons of water per acre, meaning that about three times the usual amount of clogged sand was removed per million gallons of filtered water. In warm weather, in the absence of algæ growths in the coagulating basins, and on the surface of the sand itself, such turbidities caused a less degree of clogging, and the amount of material to be removed was less than twice the normal. It is judicious with this method of purification during periods of muddy river water to apply sufficient coagulant to make the filter influent contain not much more suspended matter than could be satisfactorily removed from a water which had not been treated with a coagulant. The available evidence indicates that it would be desirable to keep the turbidity of the effluent of the coagulating basin below about 35 parts per million (about 20 parts of suspended matter), and that it would not be practicable under local conditions to use the amounts of coagulant which would be required to reduce the turbidity to below 20 parts per million, although when the river water is very clear, comparatively speaking, this condition might obtain as a matter of course, and such clearness of the applied water tends to increase the efficiency of the filter, if such were desired.

During certain periods the silica turbidity of the river water as it reached the filter without coagulation would range between the limits of from 35 to 70, or perhaps 100, parts per million. Somewhere between these limits is a point below which it would be more economical to omit a coagulant and scrape off the extra amount of clogged sand; and above which it would be more economical always to use a

coagulant. This point would not be a fixed one during all seasons of the year, but would vary somewhat, dependant upon the various conditions which would be met with in practice.

Barring complications from algæ growths which would tend to reduce the yield of the filter between scrapings, a silica turbidity of 35 parts per million (about 20 parts of suspended matter) would, on an average, permit according to available data regarding local conditions a yield of about 65 million gallons of filtered water per acre, or a period of service between scrapings of about 13 days, when a head of four feet is used. The depth of material removed would apparently average about 0.8-inch, equal in round numbers to 1.65 cubic yards of clogged sand per million gallons of filtered water. If the water applied to the filter should be as low in turbidity as 20 parts per million--silica standard--the yield of filtered water between cleanings would be considerably more, and the penetration of the clay into the sand layer would very likely be a little less. On an average, and in the absence of algæ growths, the data indicate that with such an applied water a yield of 100 million gallons per acre between scrapings, equivalent to a period of service of 20 days, could be obtained, and that the depth of sand removed by scraping would be less than 1.0 inch. It seems doubtful whether, as a rule, it would be economical under local conditions to apply sufficient coagulant to reduce the silica turbidity of the filter influent to 20 parts per million, (about 12 parts of suspended matter), although better results would probably accompany the lower turbidity.

This filter operated at double the rate of Filter No. 1, and the penetration of clay, under like conditions, was somewhat deeper than in the case of the other filter. Below are given tables which show the degree of penetration at different times. It may be noted that the degree of penetration decreased with the age of the filter and with the better preparation of the water previous to filtration. The degree of penetration of clay is shown by the amounts of iron oxid and the alumina contained in the sand samples from different depths. Clay contains both alumina and iron. The alumina must not be confused with the alumina contained in the added coagulant as only a very small portion of this goes on to the filter with the influent.

TABLE LIII.

Showing Penetration of Clay, etc., into the Sand Layer of Filter No. 2.

Date, 1901.	Depth.	Parts per Million. Clay.	Iron Oxid.	Alumina.	Albuminoid Ammonia.
	New Sand	0			5.20
Jan. 18	Surface	60 000			57.50
" 18	1 inch	45,000			12.50
" 18	6 "	9,000			10.40
Apr. 20	Surface		NOTE—No determination of Iron Oxid made; values given under "Alumina," are for Iron Oxid and Alumina.	20,600	
" 20	1 inch			3,250	
" 20	2 "			2,600	
" 20	3 "			3,430	
" 20	4 "			2,425	
" 20	5 "			3[illegible]0	
" 20	6 "			160	
May 20	Surface		2,090	6,380	
" 20	1 inch		1,335	2 400	
" 20	2 "		705	2,480	
" 20	3 "		975	2,465	
" 20	4 "		705	1 810	
" 20	5 "		70	190	
" 20	6 "		105	135	
June 5	Surface		1,765	6,650	41.0
" 5	1 inch		840	3,300	22.4
" 5	2 "		435	1,875	14.25
" 5	3 "		85	295	3.20
" 5	4 "		37	95	3.80
" 5	5 "		45	100	5.20
" 5	6 "		81	90	4.50
June 24	Surface		3,900	20,900	200.0
" 24	1 inch		360	1,775	36.0
" 24	2 "		450	990	12.5
" 24	3 "		160	140	4.15
" 24	4 "		85	150	5.15
" 24	5 "		55	120	5.25
" 24	6 "		55	125	5.50
July 5	Surface		11,000	15,000	
" 5	1 inch		190	545	
" 5	2 "		70	300	
" 5	3 "				
" 5	4 "		45	175	
" 5	5 "				
" 5	6 "		60	140	
July 29	Surface		10,000	21,600	176.75
" 29	1 inch		200	470	4.20
" 29	2 "		420	130	2.60
" 29	3 "		400	375	1 60
" 29	4 "		290	28[illegible]	2.25
" 29	5 "		225	295	1.85
" 29	6 "		260	275	2.25
Aug. 22	Surface	7,500			400.0
" 22	2 inches	4,000			16.50
" 22	4 "	900			6.75
" 22	6 "	625			12.00
" 22	1 foot	550			10.75
" 22	2 feet	240			6.25
" 22	3 "	220			6.00

Regarding the question of algæ growths, it is noted that during May they caused a reduction of the yield between scrapings to about one-half the normal. At times this reduction would be even more than this. These growths, however, retain the suspended matter in the water at and nearer the surface of the sand than when they are absent, thus preventing in part their deep penetration. Taking all the local conditions into consideration, it is believed that with a rate of 5 million gallons per acre daily, it would be judicious to cover the filters. Covers would apparently affect the total cost of filtered water but little, and would certainly be safer. A point for consideration here is, that covers save much time for the laborers in cleaning the filters during rainy weather. It is not at all unlikely that the covers would bring about a reduction in the operating expenses sufficient to offset the capital charges in the cost of construction of the covers, some $20,000 per acre.

With regard to the size of the coagulating basin, the evidence shows that its capacity could not advantageously be reduced to less than one day's flow. With suitable baffles it would not be necessary to increase this size.

It would not seem necessary to cover the entire area of the coagulating basin to prevent algæ growths. Most of the algæ growths occurred on and near the walls of the basin, and were not prevalent in the main body of water except as detached from the walls by the action of the wind. As the evidence now stands, it would be judicious to put a covering 10 feet wide so as to shade all the walls and baffles, leaving the main portion of the basin uncovered. This covering would serve to prevent the penetration of light to the walls of the basin, the breeding-place of microscopical organisms.

AMOUNT OF COAGULANT REQUIRED FOR WATERS OF DIFFERENT TURBIDITIES.

From Tables LIV and LV, given below, it may be seen that the amounts of coagulant applied to the water after being settled for 48 hours were rather too low during the first 6 weeks of operation to prepare the water satisfactorily for subsequent filtration. During the remainder of the investigation the amounts of coagulant used on an average correspond very closely with the quantities which could be used to best advantage in practice.

By plotting the turbidity of the subsided water and the amounts of coagulant used during the main portion of the investigation, the following table was prepared: Turbidity co-efficient = 0.80.

TABLE LIV.

With Subsided Mississippi River Water.

Silica Turbidity. Parts per Million.	Suspended Matter. Parts per Million.	Sulphate of Alumina. Grains per Gallon.
50	40	1.60
100	80	1.90
150	120	2.25
200	160	2.50
250	200	2.70
300	240	2.95
400	320	3.55
500	400	4.10

During the last two months of the investigation coagulant was applied directly to the river water without preliminary subsidence when it was found that absorption of coagulant by the suspended matter, as is explained in Chapter I, existed. It was, therefore, found necessary to use more coagulant to treat a given amount of suspended matter than in the case with subsided water. The required quantities of coagulant for river water of different turbidities, according to the available data, are as follows: Turbidity co-efficient = 1.08.

TABLE LV.

With Unsubsided Mississippi River Water.

Silica Turbidity. Parts per Million.	Suspended Matter. Parts per Million.	Sulphate of Alumina. Grains per Gallon.
150	160	3.05
200	220	3.40
250	270	3.75
300	325	4.10
400	430	4.85
500	540	6.10
600	650	7.70
700	760	9.30
800	860	10.95
900	970	12.60

The above tables are representative of average observed conditions. With certain classes of water these quantities of coagulant might have to be increased by as much as 25 per cent; with other waters they might be decreased in about the same ratio.

Data are lacking in both tables to show in precise terms the quantities of coagulant which would be required with higher amounts of

suspended matter than are given in the table; but from scattering observations it appears that an. extension of the curve obtained by plotting the results given in the above tables would follow quite closely the general direction of the latter portion of this curve.

Comparing these amounts of coagulant required for the various degrees of turbidity, both for river water and subsided water, wifh those considered to be necessary at Cincinnati and some other places, it is seen that the quantities given in the above tables are relatively higher. It is considered, however, that this is wholly accounted for by the peculiar character of the suspended matter contained in the local river water, and by the greater degree of classification and coagulation secured.

ECONOMICAL LIMITS OF PLAIN SUBSIDENCE FOR THE PREPARATION OF RIVER WATER FOR THIS METHOD OF PURIFICATION.

Knowing the average percentages of removal of turbidity from the river water by plain subsidence for different periods, as estimated on page 101 of Chapter III, and knowing the relation which exists between the amount of coagulant required to treat the water, as above stated, and the turbidity remaining in the water after treatment, it is possible to decide upon the arrangement which would be most economical to adopt in practice. A comparison of the relative amounts of coagulant which would be required for river water and settled water of the same turbidity, respectively, shows at once that it would not be judicious or economical to omit plain subsidence entirely.

It is cheaper to clarify this river water without a coagulant up to a certain limit, beyond which it is cheaper and better to use a coagulant. This limit can be estimated from the foregoing data, together with the capital charges upon the cost of construction of subsiding basins of different capacities.

For the purpose of comparison, the approximate cost of construction of these basins is taken as $6,000 per million gallons capacity. This cost is the cost of storing a million gallons of water for 24 hours. The capital charges are taken at 5 per cent per annum.

The cost of coagulant is taken at $25 per ton, equivalent to $1.79 per million gallons for each grain of coagulant per gallon.

These factors may be compared as follows:

TABLE LVI.

Period of Subsidence. Hours.	Remaining Turbidity of Subsided Water. Parts per Million.		Required Sulphate of Alumina. Grains per Gallon.	Cost per Million Gallons Treated.			
	Silica. Stand.	Suspended Matter.		First Cost.	Capital Charges.	Cost of Sulphate of Alumina.	Total Cost.
12	485	435	4.00	3,000	$0.41	$7.14	$7.55
24	430	360	3.70	6,000	.82	6.60	7.42
48	380	300	3.45	12,000	1.64	6.15	7.79
72	350	265	3.25	18,000	2.47	5.80	8.27

The above estimate shows that within the limits of accuracy of the data used there would be but little difference in the cost of filtered water, whether plain subsidence were practiced for 12, 24 or 48 hours. The advantage seems to be slightly in favor of 24 hours, and the 12-hour period is slightly cheaper than the 48-hour period. A period of 72 hours would be distinctly more expensive than the others.

Taking everything into consideration, including the smaller area of the basins from which sediment would have to be removed, and the smallar area of ground, it is concluded that under the local conditions and circumstances the plain subsiding basins need not be larger than one-half of the daily capacity to be provided for.

FILTER CONSTRUCTION.

The construction of filters is so thoroughly described elsewhere that it is unneccessary to note more than a few of the leading features in this connection.

As to the sand layer; 3 feet of the sand used during these investigations would be satisfactory. This sand had an effective size of 0.38 millimeters. To guard against bacterial growths within the sand layer itself, it would be well to wash the sand thoroughly before it is put in place, in order to remove pieces of leaves and other vegetable matter.

Concerning the net yield, or rate af filtration, it would be safe to make estimates based upon a rate of 4 million gallons per acre daily. The actual rate could be sufficiently higher than this with a suitable clear water basin to offset delays due to cleaning and to provide for periods of maximum consumption. While this rate is higher than has been usually recommended, it is not without precedent; as a still

higher rate is used at Zurich, in Switzerland, with satisfactory results after the water is given an adequate preparatory treatment. This rate would be safe at New Orleans on account of the thorough preparation of the water previous to filtration; the absence of freezing weather; and the relatively high average temperature of the water, which facilitates to some degree the work of a filter of this type.

COST OF PURIFICATION BY THIS METHOD.

A plant for purifying water according to this method—the modified English system—would comprise plain subsiding basins without covers, and holding 12 hours flow; a coagulating basin with the walls protected from the light by shades, and holding 24 hours' flow; a covered English filter, on the basis of one acre of filtering surface to 4 million gallons of water consumed on the average daily, and a clear water basin to hold about one quarter of the daily output of the plant.

For the purpose of estimates, the complete cost of plain subsiding reservoirs may be taken at $6,000 per million gallons daily capacity; coagulating basins at $7,000 per million gallons; and covered filters at $70,000 per acre. For the sake of simplicity, the cost of pumping stations is omitted from the comparison. The cost of clear water basins is estimated at $160,000.

On the above basis, the cost of a plant having a net capacity of 40 million gallons would be $1,260,000. At 5 per cent per annum the capital charges, interest and depreciation would be $4.31 per million gallons of water filtered.

The necessity of adequate supervision and attendance is obvious. The plant should be operated under the supervision of a director, assisted by two analysts and a messenger. There should also be three filter foremen and the necessary filter men and laborers. The cost of the labor necessary to remove, wash and replace the sand is included in the cost of scraping, which also covers attendance of regulating valves, lost time of men regularly on payrole, and care of grounds. It is estimated that the cost of supervision and attendance, including the maintenance of the office and laboratory, would be $0.94 per million gallons of water filtered.

The cost of cleaning the basins is estimated at $0.25, and you advise me that the total cost of pumping would be $2.23 per million gallons of water filtered.

Ordinary repairs could probably be made by the regular force, and it is estimated that $1,000 yearly would cover the cost of the necessary small supplies.

The cost of scraping, including the washing and replacing of sand is estimated at $2.06 per million gallons of effluent, equivalent to a removal of 1.65 cubic yards per million gallons at $1.25 per cubic yard of clogged material removed.

TOTAL COST OF PURIFICATION.

The total estimated cost of purification by a plant of 40 million gallons daily capacity, per million gallons purified, by such a system as is outlined above is itemized as follows:

Capital charges, basins and filters	$ 4.31
Double lowlift pumping, including capital charges and operation	2.23
Sulphate of alumina	6.60
Scraping filters and washing sand	2.06
Supervision and attendance	.94
Cleaning basins	.25
Miscellaneous supplies	.07
	$16.46

CONCLUSION.

These investigations have demonstrated that the modified English system is adaptable to the purification of the Mississippi River water, and at an estimated cost of $16.46 per million gallons,

CHAPTER VI.

Description of the Operation of the American System, and Discussion of the Leading Features Associated Therewith.

It was assumed at the beginning of these investigations that the Mississippi River water could be successfully purified by the American system of purification, Systems No. 3 and No. 4, but on account of local conditions, as is stated in the first pages of this report, the most efficient and economical sizes of certain parts of the purification plant, particularly the basins, and the proper method of operation of the same, were undetermined.

Investigation was therefore necessary to undertake the solution of the following problems:

1. The economical limit of plain subsidence for the purpose of removing the coarser and heavier particles of suspended matter.
2. The economical period of supplementary subsidence with coagulant for the purpose of preparing the water for filtration, especially during floods.
3. The minimum amount of coagulant which will give good qualitative results, especially during floods.
4. The advisability of divided application of coagulant.
5. The most suitable local sand to use in the filters.
6. The relative merits of air and mechanical agitation in connection with the washing of the filters; also the advisability of washing without agitation.
7. The proper rate of filtration for economical and efficient operation.

DESCRIPTION OF THE AMERICAN SYSTEM OF WATER PURIFICATION RECEIVING PLAIN SUBSIDED WATER, AND A SUMMARY OF THE PRINCIPAL RESULTS ACCOMPLISHED THEREWITH.

Besides the plain subsiding basins, the American system consists of three divisions. These may be classified as follows:

1. Devices for the preparation and application of coagulant.
2. The coagulating basin where coagulation and partial clarification takes place.
3. The filter, which completes the purification and the clarification of the effluent of the coagulating basin.

Water which had passed through the plain subsiding basin was first treated with the coagulant and then allowed to remain in the coagulating basin for a definite period during which the clay particles became aggregated into masses of flocculent suspended matter. Some of this flocculent matter, that portion which has a high subsiding value, settles out in the coagulating basin while the remainder passes on to the bed of sand in the filter. The latter acts as a strainer and removes the flocculent matter, leaving the water which filters through it perfectly clear and substantially free from bacteria.

There were two installations of the American system at the Water Purification Station, namely, Systems No. 3 and No. 4. They differed only in the size and arrangement of their basins, and in the method of agitating the sand in the filter during washing, as is described in Chapter II.

The initial data may be tabulated as follows:

	System No. 3.	System No. 4.
Period of plain subsidence, hours	48–12.	24–12.
Period of coagulation, hours	0.5 to 12	0.5 to 24.
Diameter of filter, feet	4.	4.
Area of filter, square feet	12.6	12.6
Depth of sand, inches	At least 30.	At least 30.
Depth of gravel, inches	6.	9.
Underdrain system	Pipe manifold and coarse metallic strainers.	Double bottom and fine metallic strainers.
Method of agitation during washing	Air.	Mechanical Agitator.
Rate of filtration, million gallons per acre daily	125.	125.
Sizes of Sand	Various, see Chapter	II. (page 74.)

Below is given an account of the leading features of operation:

1. *The operation of the chemical devices.*—The operation of these devices has been described in connection with the operation of Coagulating Basin No. 2 and needs no further explanation at this point (see pages 56 to 59).

2. *Operation of the coagulating and supplementary subsiding basins.*—The operation of these basins did not differ in any essential particular from the operation of Coagulating Basin No. 2, and beyond recalling the fact that System No. 3 was arranged to be operated as desired, with periods of coagulation of 0.5, 3, 6, 9 or 12 hours, respectively, while System No. 4 was arranged for periods of 0.5, 6, 12 or 24 hours, it is not necessary to offer further explanations.

Cleaning the basins.—The coagulating basins were cleaned twice; once during April and once during August. The latter cleaning took place after the close of the investigations.

Coagulating Basin No. 4 was divided by baffles and partitions into three compartments. When the basins were drained it was found that little or no precipitation had occurred in the compartment which represented the period subsequent to about the 18th hour of coagulation and supplementary subsidence. All of this evidence goes to show that with American filters, where the removal of coagulated suspended matter need not be carried to so great a length as in the case of System No. 2, the coagulating basin need not have a capacity of more than 18 hours flow.

3. *Operation of the filters.*—The operation of the American filter has been described very fully in other reports and need only be briefly referred to here.

Filling the filter.—The filter was filled from the coagulating basin with properly subsided and coagulated water, the flow of which was dependent upon the level of the water in the coagulating basin. When the filter was full the outlet was opened and filtration was begun.

Interchangeability of filters.—It was arranged so that either Filter No. 3 or Filter No. 4, or both together, could operate with the effluent of Coagulating Basin No. 3. This permitted the "equating" of the filters. To "equate" filters of different designs one compares their results of operation when supplied with influents which are practically identical.

Filtration.—Automatic controllers on the outlet of each filter effectively regulated their rates of filtration.

Decision to wash the filters.—It was necessary, as a rule, to operate the filter until the loss of head reached the available limit—10.7 feet—provided the appearance of the effluent was satisfactory. When it was not, the filter was washed regardless of the loss of head.

Draining the filter.—When it was decided to wash a filter, the inlet valve was closed and the water above the edge of the inner tank, (overflow gutter,) was allowed to filter through the outlet.

Washing the filter.—*Filter No. 3.*—As soon as the water above the sand had drained to about 6 or 8 inches below the top of the overflow gutter, the outlet valve was closed, the air pump was started, and air at the rate of about 5 cubic feet per minute per square foot of sand surface was pumped into the filter from below. Ordinarily, this application of air was continued for two minutes. It was then discontinued; the wash water valve was opened; and filtered water was forced up through the sand over into the overflow gutter and out through the previously opened waste overflow, carrying with it the flocculent suspended matter which had been stored up in the sand during filtration and which, by clogging the sand layer, had made washing necessary. The rate of flow of wash water varied with the size of the sand. Generally

speaking, this rate was as high as could be used and still not permit sand to be carried away with the wash water. With coarse sand—sand No. 1—a rate of 8 gallons per square foot per minute, 4 times the rate of filtration, was employed, but with the finest sands it was necessary to reduce this rate by about 25 per cent. The application of wash water for a period of from 4 to 8 minutes sufficed to cleanse the sand layer. Washing was considered complete when the waste wash water became entirely free from the coarse suspended matter and practically clean; the final portions of wash water usually had a silica turbidity of less than 150 parts of suspended matter per million. The wash water valve was then closed slowly in order to allow the separation of the sand and gravel in the filter according to their hydraulic values. After washing, the inlet valve was opened, the filter was allowed to fill, and filtration was resumed as before.

Second application of air.—At the beginning of the investigation it was the custom to admit 3 or 4 cubic feet of air at the end of washing at the rate of not over 2 cubic feet per square foot a minute and while the wash water was still entering the filter at about one-half rate. In other words, air was admitted into the filter just as rapidly as was possible without causing the sand to be projected into the overflow gutter. The intent of this procedure was to prevent the stratification of the finest portions of sand at the top of the latter, but this practice was discontinued after two months trial because it seemed to be needless with a suitable sand layer.

Filter No. 4.—Filter No. 4 was washed in a similar manner to Filter No. 3, except that the use of air was omitted and that the sand was stirred by a revolving agitator, which made 6.5 revolutions per minute, and whose rakes penetrated the sand layer, during the time when wash water was being forced up through the sand layer.

OUTLINE OF LEADING CONDITIONS OF ACTUAL OPERATION OF THE AMERICAN SYSTEM.

Before presenting the table which shows the leading results of operation, it is well to divide the description of the operation of the filters, since the systems did not follow any one procedure continuously but were operated as a series of experiments.

Data were collected during all the periods of operation to determine the proper amounts of coagulant; the proper periods of plain subsidence and coagulation with supplementary subsidence; the minimum effective amounts of wash water; the proper procedures with coagulated water of different turbidities and with various sands; the limits of loss of head, etc. Their operation, therefore, may be divided into periods dependent upon the following factors:

1. Character of the subsided water.
2. Kind of sand used.
3. Experiments to equate the filters.
4. Experiments to determine the advisability of agitation in onnection with the washing of the filters.

The operation of the two systems may be divided into periods as ollows:

OPERATION OF FILTER NO. 3

Period No. 1. December 22nd to February 1st.—During this period he filter operated with sand No. 1, class I B water—from the upper ributary—which had a silica turbidity of from 150 to 350 parts per million. During this period the devices for the application of air did ot work satisfactorily, but before Period No. 2 began this difficulty was overcome.

Period No. 2. February 27th to March 15th.—During this period he filter operated with sand No. 2, class I B water, which had a silica urbidity of from 130 to 210 parts per million.

Period No. 3. March 16th to April 10th.—During this period the lter operated with sand No. 2 and class I C water. This water was he result of a flood in the Ohio river, and had a silica turbidity of rom 110 to 1000 parts per million. During this period a few runs were made with one-half of the usual amount of coagulant.

Period No. 4. May 3rd to 21st.— During this period the ilter operated with sand No. 3 and class II water. This water parook largely of the character of the southwestern tributaries of the Mississippi River and had a silica turbidity of from 250 to 700 parts er million. During this period the filters were equated.

Period No. 5. May 21st to 31st.—During this period the filter perated with sand No. 3 and class II A water. This water partook f the character of the water of the Arkansas basin. It was difficult coagulate, especially with short periods of coagulation, and required r efficient purification amounts of coagulant 25 per cent in excess of e amounts required for average water of the same turbidity.

Period No. 6. June 1st to 11th.—This period differs from Period o. 5 in having water which partook largely of the character of the ed River water; that is, it contained a large percentage of coarse rticles of suspended matter which absorbed large amounts of coagunt, consequently, short periods of coagulation were more efficient om a bacterial standpoint and the cost of operation was not decreased lengthening the period of coagulation, as was the case with the mainder of the water experimented with during this investigation. he silica turbidity of this water varied from 350 to 625 parts per illion.

Period No. 7. June 11th to 14th.—During this period sand N
was used and the filter operated with class II water, having a s
turbidity of from 400 to 500 parts per million.

Period No. 8. June 15th to August 8th.—During this perio
filter operated with sand No. 4 and with class II water of a
turbidity of from 120 to 750 parts per million. During this p
experiments were made to show the effect of agitation upo
efficiency and economy of filtration.

Period No. 9. August 9th to 17th.—During this period the
operated with sand No. 5 and class II water, which had a silic
bidity of 90 to 150 parts. During this period experiments were
to show the effect of omitting the first application of coagulant
plying the coagulant to the water 0.5 hours before filtration.

PERIODS OF OPERATION OF FILTER NO. 4.

Period No. 1. December 19th to 21st.—This was a period of
liminary operation with sand No. 1 and water of class I A, whic
a silica turbidity of from 325 to 550 parts per million.

Period No. 2. December 22nd to February 24th.—During
period the filter was operated with sand No. 1 with class I B wa
water which had a silica turbidity of from 150 to 350 parts per mi

Period No. 3. February 28th to March 15th.—During this p
the filter was operated with sand No. 2 and with class I B water
silica turbidity of from 130 to 190 parts per million,

Period No. 4. March 16th to April 5th.—During this perio
filter was operated with sand No. 2 and class I C water, which h
silica turbidity of from 110 to 1000 parts per million. This p
closely corresponds to Period No. 3 of Filter No. 3; and dur
experiments were made to show the effect of reducing the
amounts of sulphate of alumina used as a coagulant.

Period No. 5. April 8th to 26th.—During this perio
filter was operated with sand No. 3 and with class II water of a
turbidity of from 450 to 725 parts per million.

During the first five periods the filters were operated with s
resting directly upon strainers, but as it was desired to equate t
ters, enough gravel was placed in the filter after the close of I
No. 5 to permit the operation of the two filters with the same
ness of sand layer and height of overflow gutter above the surf
the same.

Period No. 6. May 3rd to 21st.—During this period the filt
operated with sand No. 3 and with class II water of a silica tur
of from 350 to 700 parts per million. Filters No. 3 and No. 4

ated during this period by operating them under exactly similar ditions with the exception of the methods of agitation during hing.

Period No. 7. May 21st to 31st, and Period No 8, June 1st to 11th, respond to Periods No. 5 and No. 6 of Filter No. 3.

Period No. 9. June 11th to 25th.—During this period the filter rated with sand No. 3 and with class II water, having a silica turity of from 350 to 500 parts per million.

Period No. 10 June 27th to August 6th.—During this period the er operated with sand No. 4 and with class II water, having a silica bidity of from 130 to 775 parts per million.

Period No 11. August 6th to 17th.—During this period the filter rated with sand No. 5 and with class II water, having a silica turity of from 90 to 150 parts per million. During this period experitats were made to show the effect of omitting the first application of gulant as was done in Period No. 9 of Filter No. 3.

For convenient reference, the sizes and uniformity co-efficients of sands used in these two systems are tabulated as follows:

Sand No.	Effective Size; Millimeters.	Uniformity Co-efficients.
1	0.54	1.30
2	0.385	1.48
3	0.34	1.41
4	0.25	1.80
5	0.18	1.83

DESCRIPTION OF TABLES LVII AND LVIII.

In these tables, pages 142 to 169 are represented all of the leading ults of operation, arranged and averaged by runs. A run includes the operations of the filter from the time the outlet valve is opened owing a washing, until it is again opened for the next succeeding hing.

Many runs were made under abnormal conditions. These runs noted in the "remarks" column.

The data in general are self-explanatory, with the following eptions:

The periods of washing for Filter No. 3 include the time required apply the air as well as to apply the water, open and close the valves, . The percentages of wash water were sometimes increased beyond amounts required for washing, as will be seen in the tables.

The abbreviation C. B. refers to the effluent of the coagulating sin.

TABLE LVII.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water, Gallons. Filtered.	Quantities of Water, Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water	Bacterial Efficiency, Per Cent. Coagulating Basin.	Bacterial Efficiency, Per Cent. System.	Number of Run.	Remarks.
1	Dec. 22	5:18	......	...	...	300	...	...	3	......	10.60	0.32	......	845	......	...	......	......	......	......	5,200	......	...	...	1	Not enough water to [run at full rate.
2	" 22	16:43	......	...	...	300	...	...	3	2.26	15.42	0.38	23,125	755	3.3	122	......	......	2,400	......	5,000	......	...	...	2	
3	" 23	8:31	......	...	.	......	...	...	3	2.25	7.85	0.33	11,775	688	5.8	120	......	......	2,200	......	......	......		...	3	
4	" 23	16:42	......	...	...	......	...	...	3	1.30	4.53	0.43	6,800	718	10.6	114	......	......	1,900	......	......	......	...	...	4	
5	" 23	21:40	......	...	...	......	...	...	3	2.67	6.67	0.38	10,000	777	7.8	118	......	......	1,800	......	......	......	...	...	5	
6	" 24	4:43	......	...	...	260	...	...	3	2.86	4.53	0.38	6,800	665	9.8	115	......	......	1,600	......	1,300	......	...	...	6	
7	" 24	9:38	......	...	...	260	..	...	3	2.14	4.80	0.53	7,200	1,047	14.5	113	......	......	1,400	......	1,500	......	...	...	7	
8	" 24	14:58	......	...	...	260	...	...	3	1.98	7.45	0.48	11,175	1,024	9.2	117	......	......	1,200	......	1 700	......	...	...	8	
9	" 24	22:54	......	...	...	260	...	...	3	2.42	7.47	0.50	11,200	830	7.4	117	......	......	1,400	......	1,900	......	...	...	9	
10	" 25	6:52	......	...	...	250	...	...	3	2.79	7.48	0.50	11,225	867	7.7	117	......	......	1,500	......	2,500	......	...	...	10	
11	" 25	14:51	......	...	...	250	...	...	3	2.28	7.35	0.47	11,025	905	8.2	117	......	......	1,600	......	2,500	......	...	...	11	
12	" 25	22 40	......	...	...	250	...	...	3	2.49	7.60	0.43	11,400	748	6 6	118	......	......	1,700	......	4,000	......	...	...	12	
13	" 26	6:42	155	55	65	200	...	...	3	2.82	7.57	0.43	11 375	964	8.5	118	......	......	1,800	......	6,500	......	...	...	13	
14	" 26	14:43	155	55	65	200	...	...	3	2.54	7.67	0.45	11,500	942	8.2	118	2.5	3.8	1,700	......	6,500	......	...	...	14	
15	" 26	22:50	155	55	65	200	...	...	3	2.61	7.12	0.47	10,675	1,241	11.6	118	2.2	......	1,700	......	6 500	......	...	...	15	
16	Jan. 1	22:38	105	31	70	......	...	...	3	2.74	20.75	0.42	31,125	905	2.9	122	2.3	5.0	1 500	......	2,000	......	...	...	16	
17	" 3	7:42	120	60	50	160	70	56	3	1.49	5.63	0.38	8,450	1,570	18.6	117	2.1	3.0	1.800	......	1,600	......	...	...	17	
18	" 3	13:43	160	60	68	160	70	56	3	2.70	16.75	0.35	23,625	785	3.3	122	2.2	4.3	2,000	......	1,200	......	...	...	18	
19	" 4	6:49	205	5	98	160	45	72	3	3.17	24.40	0.42	36,600	246	0.7	123	2.1	5.3	2,100		275	......	...	...	19	
20	" 5	7:38	175	25	86	160	50	69	3	3.42	12.10	0.33	18,160	956	5.3	122	2.5	4.2	600	3,000	700	220	93	63	20	
21	" 6	2:07	160	40	75	160	50	69	6	3.25	7.10	0.42	10,650	951	8.9	118	2.5	4.3	600	2,300	......	300	87	50	21	
22	" 6	9:38	150	85	43	160	100	38	6	1.51	0.94	0.32	1,425	608	43.2	93	2.6	......	600	1,600	......	350	78	42	22	Previous wash bad. [Washed over.
23	" 6	10:53	150	40	73	160	50	69	6	3.64	10.43	0.47	15,650	900	5.8	109	2.5	4.1	600	1,600	......	400	75	33	23	
24	" 6	21:39	140	40	71	160	50	69	6	2.91	9.52	0.33	14,275	1,141	8.0	121	2.4	3.4	600	1,600	......	450	72	25	24	
25	" 7	7:30	130	50	62	160	60	63	6	2.05	7.87	0.28	11,800	621	5.3	121	2.4	3.2	......	......	......	......	...	...	25	
26	" 7	15:39	120	50	58	150	60	60	6	3.61	10.77	0.28	16,150	678	4.2	122	2.5	3.9		......	......	......	...	...	26	
27	" 8	2:42	120	40	67	140	70	50	6	3.06	7.75	0.16	11,625	480	4.1	122	2.6	3.6	......	1 400	......	900	86	...	27	
28	" 8	23:37	120	35	71	130	60	54	9	3.28	14.07	0.32	21,150	412	1 9	122	3.6	4.0	1,400	550	......	60	89	96	28	
29	" 9	14:00	115	30	73	120	50	58	9	3.77	12.48	0.27	18,750	410	2.2	122	3.1	4.5	1,100	1,500	380	200	87	82	29	
30	" 10	2:45	105	30	71	130	45	65	9	3.86	24.92	0.27	37,375	581	1.5	124	2.4	4.4	1,300	1,900	220	500	74	62	30	
31	" 11	3:56	95	25	74	120	40	67	9	3.60	23.48	0.30	35,025	585	1.7	124	2.5	4.3	850	2,300	550	140	94	84	31	

35	"	15	7:38	100	24	76	120	35	71	12	3.88	23.78	0.30	35,700	628	1.8	123	2.5	4.0	800	1,100	150	40	96	95	35	
36	"	16	7:43	130	30	77	120	45	63	12	3.74	23.65	0.32	35,500	723	2.0	124	2.4	4.6	350	230	34	10	96	97	36	
37	"	17	7:41	160	12	93	150	40	73	12	3.71	7.43	0.28	11,150	541	4.8	120	2.4	3.1	250	350	32	3	99	99	37	
38	"	17	15:34	155	17	89	170	55	68	12	3.28	3.57	0.28	5,350	496	9.3	116	2.8	3.1	240	350	80	10	97	96	38	
39	"	18	7:02	150	11	93	160	45	72	9	2.78	19.42	0.28	29,450	519	1.7	123	2.6	4.0	250	300	140	17	94	93	39	
40	"	19	2:44	135	11	92	170	45	74	9	3.39	6.43	0.28	9,650	566	5.9	120	2.6	.....	950	1,500	225	50	97	95	40	
41	"	19	9:27	135	11	92	160	45	72	9	3.28	17.02	0.27	25,350	514	2.0	123	2.6	3.8	1,100	1,300	300	90	93	92	41	
42	"	20	2:44	135	33	76	150	60	60	9	3.22	10.49	0.25	15,125	573	3.6	122	2.6	3.3	1,100	1,000	375	110	89	90	42	
43	"	20	21:02	130	33	75	140	60	57	6	3.44	7.52	0.25	11,300	549	4.9	121	2.4	3.4	700	900	325	120	87	83	43	
44	"	21	4:48	130	32	75	130	55	58	6	3.19	4.77	0.25	7,150	530	7.4	119	2.5	3.1	700	800	280	80	90	89	44	
45	"	21	16:02	125	32	74	130	60	54	6	4.05	10.28	0.26	15,450	529	3.4	122	2.4	3.6	800	750	280	80	89	90	45	
46	"	22	2:35	115	35	70	130	50	62	6	4.07	7.78	0.26	11,675	601	5.1	121	2.5	3.4	800	700	275	70	90	91	46	
47	"	22	16:00	110	35	68	130	50	62	6	4.71	11.87	0.23	17,800	507	2.8	123	2.5	4.0	700	650	200	65	90	91	47	
48	"	23	4:06	105	35	67	130	50	62	6	4.88	8.08	0.26	12,125	612	5.0	121	2.6	3.6	700	600	120	40	93	94	48	
49	"	23	12:28	110	35	68	130	50	62	6	4.95	13.37	0.25	20,050	524	2.6	123	2.5	4.3	500	550	115	25	95	95	49	
50	"	24	2:05	110	35	68	120	50	58	6	4.86	9.75	0.30	14,650	696	4.7	122	2.6	3.9	500	450	110	21	95	96	50	
51	"	24	18:02	110	35	68	120	50	58	6	3.33	10.22	0.25	15,350	521	3.4	122	2.5	3.8	500	400	110	17	96	97	51	
52	"	25	4:51	120	38	68	130	55	58	6	3.47	8.42	0.27	12,625	577	4.6	121	2.5	3.5	600	400	85	9	98	99	52	
53	"	25	19:02	120	38	68	130	55	58	6	2.63	7.38	0.30	10,325	555	5.4	120	2.5	3.4	600	400	90	13	97	98	53	
54	"	26	2.40	130	35	73	130	50	62	6	2.59	8.63	0.25	12,950	623	4.8	121	2.6	3.6	600	450	100	15	97	98	54	
55	"	26	16:30	135	35	74	130	50	62	6	2.01	7.87	0.25	11,800	515	4.4	121	2.7	3.4	600	450	100	23	95	96	55	
56	"	26	21:37	140	35	75	130	50	62	6	2.08	5.23	0.27	7,825	555	7.1	119	2.6	3.4	600	425	100	9	98	99	56	
57	"	27	8:03	145	40	72	130	50	62	6	3.81	6.30	0.27	9,450	586	6.2	122	2.6	3.3	650	550	100	13	98	98	57	
58	"	27	14:37	140	40	71	130	50	62	6	3.28	12.00	0.25	18,000	525	3.4	123	2.5	3.8	650	550	110	30	94	95	58	
59	"	28	2:52	135	40	71	140	55	61	6	3.45	6.53	0.33	9,850	622	6.3	119	2.4	4.1	600	425	120	15	97	98	59	
60	"	28	10:24	130	40	69	140	55	61	3	3.33	5.10	0.27	7,650	563	7.3	119	2.4	3.3	600	425	120	14	98	98	60	
61	"	28	15 46	125	40	68	140	55	61	3	3.36	8.37	0.25	12,550	525	4.2	122	2.5	3.8	600	425	125	14	98	98	61	
62	"	29	00:23	120	40	67	140	55	61	3	3.33	2.68	0.25	4,020	532	13.2	116	2.7	3.2	600	425	130	46	89	92	62	
63	"	29	3:22	120	50	58	130	110	15	3	3.35	3.84	0.29	5,750	584	10.2	116	2.5	3.2	600	375	120	11	97	98	63	
64	"	29	7:29	120	50	58	130	110	15	3	3.36	1.77	0.25	2,650	571	21.5	109	2.5	2.9	600	375	110	...	...	...	64	
65	"	29	18:02	130	50	62	130	110	15	9	3.36	15.40	0.27	23,100	604	2.6	12[illegible]	2.4	3.5	......	375	100	9	98	...	65	
66	"	30	9:42	150	30	80	150	35	77	9	3.33	23.68	0.23	35,050	517	1.5	124	2.4	4.3	......	400	95	17	96	...	66	
67	"	31	17:32	180	40	78	170	40	76	9	2.66	16.02	0.30	24,050	671	2.8	123	2.6	3.6	......	950	200	45	95	...	67	
68	Feb.	1	1[illegible]:03	170	45	73	180	55	69	9	1.67	12.55	0.27	18,800	608	3.2	122	2.5	3.6	......	......	290	...	...	...	68	
69	"	25	2:30	165	30	82	180	30	83	12	2.61	23.13	0.27	34,700	577	1.6	123	1.7	3.1	3,200	4,000	140	55	99	98	69	New sand put in for experi- [mental purposes.
70	"	26	1:38	160	30	81	170	30	82	12	2.34	18.95	0.17	28,400	517	1.8	123	1.6	2.9	3,800	3,300	475	55	98	99	70	
71	"	27	15:51	150	30	80	160	35	78	12	2.43	34.82	0.25	52,200	678	1.3	124	3.1	10.8	2,800	2,300	425	...	...	...	71	New sand put in.
72	Mar.	1	9:26	140	35	75	140	40	71	12	2.42	1.50	0.17	1,750	301	17.2	116	2.8	3.1	1,400	1,300	200	...	...	...	72	
73	"	1	17:57	130	35	73	140	40	71	12	2.48	34.43	0.20	51,600	537	1.0	124	3.1	10.8	1,400	1,300	150	100	92	93	73	
74	"	3	4:38	120	14	88	120	24	80	12	2.39	28.66	0.22	43,000	584	1.3	124	2.7	8.3	2,400	3,300	110	20	97	92	74	
75	"	4	9:31	110	13	88	120	23	81	12	2.24	31.93	0.23	47,900	626	1.3	124	2.6	9.4	1,600	1,400	100	40	97	98	75	
76	"	5	19:45	115	8	93	160	13	92	9	2.24	22.62	0.17	33,900	485	1.4	124	2.8	8.1	1,200	950	90	22	98	98	76	
77	"	6	18:32	125	20	84	150	21	86	9	2.37	31.55	0.18	47.300	446	1.0	124	2.8	7.7	1,000	750	90	16	98	98	77	
78	"	8	2:1	120	27	78	140	21	85	9	2.41	26.33	0.20	39,500	423	1.1	124	3.0	8.4	800	850	65	24	98	97	78	
79	"	9	4:48	110	11	90	130	20	85	9	2.34	16.50	0.20	24,700	401	1.6	124	2.8	10.8	950	475	55	15	97	98	79	Run broken because [of low water level in basins.
80	"	9	21:30	105	13	88	130	24	81	9	2.35	13.03	0.18	19,500	483	2.5	123	2.6	7.4	950	475	60	15	97	98	80	
81	"	10	10:43	90	19	79	140	35	75	9	2.28	19.97	0.20	29,900	555	1.8	124	2.6	7.5	600	500	70	40	92	93	81	
82	"	11	6:53	90	21	77	110	35	68	9	2.10	21.48	0.22	32,200	450	1.4	124	2.7	6.9	600	475	55	12	97	98	82	

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began.		Suspended Matter.			Silica Turbidity.			Period of Coagulation.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
	Date, 1900-1901.	Hour.	Parts per Million. Subsided Water.	Parts per Million. Coagulated Water.	Per Cent. Removed.	Parts per Million. Subsided Water.	Parts per Million. Coagulated Water.	Per Cent. Removed.	Hours.		Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
83	Mar. 12	4:35	95	19	80	130	30	77	9	2.06	20.50	0.22	30,700	503	1.6	124	2.7	6.8	700	700	75	60	91	91	83	
84	" 13	1:18	100	30	70	100	40	60	9	1.70	15.62	0.22	23,400	529	2.3	123	2.5	5.7	800	900	125	30	97	96	84	
85	" 13	17:01	105	30	71	100	40	60	9	1.62	15.58	0.20	23,300	566	2.4	123	2.6	5.5	800	900	175	80	91	90	85	
86	" 14	8:54	110	50	55	110	50	55	9	1.23	19.32	0.22	28 900	495	1.7	124	2.6	6.3	750	1,400	210	180	87	76	86	
87	" 15	4:26	105	50	52	110	50	55	6	1.66	8.18	0.18	12,300	551	4.5	122	2.7	4.3	750	450	300	34	92	95	87	
88	" 15	12:48	100	70	30	110	80	27	6	1.71	9.82	0.23	14,900	484	3.2	122	2.7	4.7	600	450	370	55	88	91	88	
89	" 15	22:51	100	70	30	110	80	27	6	1.72	7.90	0.18	11,900	521	4.4	122	2.7	4.4	600	450	300	46	90	92	89	
90	" 16	6:56	95	65	32	100	70	30	6	1.72	7.35	0.18	11,000	507	4.7	122	2.8	4.3	500	325	250	16	95	97	90	
91	" 16	14:28	90	65	28	80	70	13	6	1.71	8.35	0.22	12,500	488	3.9	120	2.8	4.4	500	325	200	50	85	90	91	
92	" 16	23:02	85	65	24	100	70	30	6	1·64	7.43	0.18	11,200	533	4.8	122	2.7	4.3	500	325	250	40	88	92	92	
93	" 17	6:39	80	30	63	100	60	40	6	1.62	4.27	0.27	6.400	520	8.7	118	2.7	3.6	750	2,500	200	38	99	95	93	Washed for exhibi- [tion.
94	" 17	11:13	75	30	60	100	60	40	6	1.61	6.32	0.16	9,500	469	4.9	122	2.9	4.3	750	2,500	130	35	99	95	94	
95	" 17	17:42	70	30	57	100	60	40	6	1.61	8.52	0.23	12,800	499	3.9	121	2.7	4.4	750	2,500	150	70	97	91	95	
96	" 18	2:27	65	35	46	90	65	28	6	1.61	7.60	0.16	11,400	439	3.8	122	2.6	4.2	1,100	750	170	50	93	95	96	
97	" 18	10:25	60	40	33	80	70	13	6	1.62	7.13	0.18	10,700	506	4.7	122	2.6	4.1	1,100	750	200	120	84	89	97	
98	" 18	17:44	60	45	25	70	75	...	6	1.19	8.68	0.20	13,000	458	3.5	122	2.6	4.6	1,100	750	170	100	87	91	98	
99	" 19	2:37	60	40	33	80	70	13	6	1.25	7.12	0.18	10,700	518	4.8	122	2.6	4.1	800	550	150	90	84	89	99	
100	" 19	9:55	60	40	33	85	70	18	6	1.25	9.30	0.20	13,950	498	3.6	122	2.6	4.6	800	550	130	70	87	91	100	
101	" 19	19:15	60	55	9	85	85	0	3	1.21	8.22	0.16	12,300	465	3.8	122	2.4	5.4	800	550	130	140	75	83	101	
102	" 20	3:38	65	60	8	80	80	0	3	1.84	5.48	0.18	8,200	510	6.2	121	2.6	4.3	900	700	180	110	84	88	102	
103	" 20	9:18	65	60	8	85	80	6	3	1.84	5.57	0.18	8 550	495	5.9	121	2.5	4.3	900	700	180	65	91	93	103	
104	" 20	15:03	65	60	8	90	80	11	3	1.34	6.33	0.22	9,500	514	5.4	121	2.6	4.4	900	700	180	100	86	89	104	
105	" 20	21:36	65	60	8	100	80	20	3	1.34	6.73	0.20	10,100	639	6.3	121	2.5	4.8	900	1,500	180	110	93	88	105	
106	" 21	4:32	60	35	40	110	65	41	3	1.83	8.05	0.16	12,100	531	4.4	122	2.6	4.7	1,600	1,500	200	65	96	96	106	
107	" 21	12:46	60	55	9	75	75	0	3	1.57	9.70	0.16	14,600	439	3.0	123	2.6	4.5	1,600	1,500	275	70	95	96	107	
108	" 21	22:39	60	60	0	85	80	6	3	1.71	6.43	0.20	9,600	513	5.3	121	2.4	4.4	1,600	4,000	275	100	98	94	108	
109	" 22	5:17	60	65	0	90	90	0	3	1.72	3.93	0.18	5,900	510	8.6	119	2.5	3.6	800	4,000	275	110	97	86	109	
110	" 22	9:24	60	65	0	90	90	0	3	1.73	4.03	0.18	6,000	516	8.6	119	2.6	3.7	800	4,000	275	100	98	88	110	
111	" 22	13:37	60	65	0	90	90	0	3	1.76	3.65	0.16	5,500	469	8.5	120	2.5	3.5	800	4,000	275	37	99	75	111	
112	" 22	17:26	60	65	0	90	90	0	3	1.86	5.10	0.18	7,600	450	5.9	121	2.6	3.8	800	4,000	275	200	95	75	112	
113	" 22	22:43	60	65	0	90	90	0	3	2.08	3.68	0.20	5,500	483	8.8	118	2.6	3.8	800	4,000	275	275	93	66	113	

114	Mar.	23	2:36	75	65	18	120	100	17	3	2.00	4.52	0.16	6,800	443	6.5	121	2.6	3.9	......	7,800	....	300	96	......	114	
115	"	23	7:17	75	65	18	120	100	17	3	2.03	2.92	0.16	4,400	450	10.2	118	2.6	3.5	......	7,800	....	250	97	......	115	
116	"	23	10:22	75	65	18	120	100	17	3	2.02	3.25	0.18	4,900	529	10.8	118	2.6	3.6	......	7,800	....	......	......	......	116	
117	"	23	13:48	75	65	18	120	100	17	3	2.01	3.02	0.22	4,500	360	8.0	116	2.6	3.5	......	7,800	....		......	......	117	
118	"	23	17:02	75	65	18	120	100	17	3	2.02	4.72	0.20	7,100	417	5.9	120	2.6	3.9	......	7,800	....	700	91	......	118	
119	"	23	21:57	75	65	18	120	100	17	3	2.67	3.92	0.20	5,900	480	8.1	119	2.4	3.7	......	7,800	....	......	......	..	119	
120	"	24	2:04	115	70	39	160	85	47	3	2.64	3.10	0.18	4,700	413	8.7	118	2.3	3.6	3,000	13,000	....	400	97	87	120	
121	"	24	5:21	115	70	39	160	85	47	3	2.59	3.08	0.18	4,500	499	11.1	118	2.5	3.6	3,000	13,000	....	250	98	92	121	
122	"	24	8 34	115	70	39	160	85	47	3	2.66	2.10	0.16	3,100	420	13.5	116	2.5	3.2	3,000	13,000	....	200	98	93	122	
123	"	24	10:50	115	70	39	160	85	47	3	2.64	2.28	0.16	3,400	431	12.6	117	2.5	3.1	3,000	13,000	....	......	......	......	123	
124	"	24	13:17	115	70	39	160	85	47	3	2.69	2.30	0.16	3,450	431	12.5	117	2.5	3.2	3,000	13,000	....	......	......	......	124	
125	"	24	15:45	115	70	39	160	85	47	3	2.66	1.75	0.16	2,600	435	16.7	118	2.5	3.1	3,000	13,000	....	......	......	......	125	
126	"	24	17:40	115	70	39	160	85	47	3	2.64	2.78	0.16	4,200	424	10.1	118	2.5	3.3	3,000	13,000	....	250	98	92	126	
127	"	24	20:37	115	70	39	160	85	47	3	2.66	2.58	0.18	3,900	488	12.5	117	2.4	3.3	3,000	13,000	....	......	......		127	
128	"	24	23:23	115	70	39	160	85	47	3	2.64	2.23	0.18	3,300	442	13.4	116	2.4	3.8	3,000	13,000	....	220	98	93	128	
129	"	25	1:48	120	75	38	160	100	38	3	2.61	2.32	0.16	3,500	439	12.5	117	2.4	3.3	6,500	6,000	90	160	97	98	129	
130	"	25	4:17	130	75	42	160	100	38	3	2.64	2.38	0.16	3,600	405	11.2	117	2.6	3.3	6,500	6,000	90	75	99	99	130	
131	"	25	6:50	180	75	58	160	100	38	3	2.64	2.28	0.16	3,400	405	11.9	117	2.5	3.1	6,500	6,000	90	20	99	99	131	
132	"	25	22:03	140	75	46	160	100	38	12	2.83	8.57	0.16	12,900	444	3.4	123	2.4	3.6	6,500	6,000	90	90	99	99	132	
133	"	26	6:47	190	25	87	250	40	84	12	2.81	24.25	0.18	36,400	480	1.3	124	2.6	4.9	6,500	2,400	375	65	97	99	133	
134	"	27	7:23	370	10	97	370	30	92	12	4.65	33.28	0.18	49,900	517	1.0	124	2.5	5.9	6,000	6,000	250	40	99	99	134	
135	"	28	16:51	540	80	85	375	95	75	12	5.67	23.75	0.18	35,600	512	1.4	124	2.5	5.5	3,800	2,800	275	40	99	99	135	
136	"	29	16:47	470	70	85	450	85	81	12	4.63	4.53	0.20	6,800	521	7.6	120	2.6	3.5	1,500	3,900	500	75	98	95	136	
137	"	29	21:31	450	70	85	450	85	81	12	3.93	2.07	0.18	3,100	529	17.0	115	2.6	3.2	1,500	3,900	500	130	97	91	137	
138	"	30	11:32	400	120	70	475	125	74	12	0.96 3.38	10.22	0.18	15,300	490	3.2	123	2.6	3.4	2,900	2,400	425	45	98	98	138	Began secondary application of coagulation 30 minutes before reaching Filter.
139	"	30	21:56	400	120	70	475	125	74	12	0.96 3.16	7.62	0.18	11,400	492	4.3	122	2.5	5.0	2,900	2,400	425	80	97	97	139	
140	"	31	5:44	400	120	70	520	130	75	12	0.87 3.04	8.47	0.18	12,700	532	4.2	122	2.7	4.9	......	4,100	425	275	93	......	140	
141	"	31	14:23	400	120	70	520	130	75	12	0.97 3.17	3.50	0.18	5,250	494	9.4	119	2.5	4.1	......	4,100	425	50	99	......	141	
142	"	31	18:04	400	120	70	520	130	75	12	0.98 3.33	5.15	0.18	7,700	450	5.8	121	2.6	4.1	......	4,100	375	70	98	......	142	
143	"	31	23:24	400	120	70	520	130	75	12	0.97 3.78	5.77	0.18	8,650	487	5.6	121	2.5	4.2	......	4,100	350	38	99	......	143	
144	Apr.	1	5:21	400	75	81	530	150	72	12	1.02 3.78	8.08	0.18	12,100	520	4.3	122	2.6	4.9	5,000	1,800	325	17	99	99	144	
145	"	1	13:37	400	75	81	530	150	72	12	1.46 3.76	7.48	0.18	11,200	521	4.7	122	2.5	5.0	5,000	1,800	300	12	99	99	145	
146	"	1	21:17	400	75	81	530	150	72	12	1.49 3.56	4.95	0.18	7,400	536	7.2	120	2.5	4.5	5,000	1,800	250	18	99	99	146	
147	"	2	2:25	385	70	82	510	140	73	12	1.50 3.51	3.25	0.18	4,900	554	11.3	118	2.5	4.1	4,800	2,700	200	21	99	99	147	
148	"	2	22:32	380	70	82	510	140	73	12	1.50 3.78	13.96	0.18	20,900	544	2.6	123	2.3	3.3	4,800	2,700	110	......	......	......	148	
149	"	3	12:41	375	85	77	460	65	86	12	1.49 3.78	5.08	0.18	7,600	555	7.3	123	2.6	4.6	4,000	2,750	300	......	......	......	149	
150	"	3	17:57	370	85	77	460	65	86	12	1.51 3.78	3.52	0.18	5,300	514	9.7	119	2.7	4.4	4,000	2,800	375	8	99	99	150	
151	"	3	21:39	370	85	77	460	65	86	12	1.50 3.67	4.50	0.16	6,750	435	6.4	120	2.5	4.6	4,000	2,800	375	10	100	100	151	

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began.		Suspended Matter.			Silica Turbidity.			Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
			Parts per Million.			Parts per Million.																				
	Date, 1900-1901.	Hour.	Subsided Water.	Coagulated Water.	Per Cent. Removed	Subsided Water.	Coagulated Water.	Per Cent. Removed.			Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
152	Apr. 4	2:19	360	100	72	410	150	64	12	1.51 3.36	3.80	0.18	5,700	528	9.2	119	2.5	4.2	4,500	2,200	950	12	100	100	152	
153	" 4	6:18	355	100	72	410	150	64	12	1.51 3.30	2.37	0.16	3,550	454	12.8	117	2.5	3.7	4,500	2,200	950	20	99	100	153	
154	" 4	8.50	350	100	71	410	150	64	12	1.48 3.31	2.75	0.16	4,100	486	11.7	118	2.6	3.8	4,500	2,200	950	12	100	100	154	
155	" 4	11:45	345	100	71	410	150	64	12	1.51 3.33	1.48	0.18	2,200	488	22.2	111	2.5	3.6	4,500	2,200	950	...	.....	.....	155	
156	" 4	13:25	310	100	70	410	150	64	12	1.49 2.68	2.77	0.18	4,150	472	11.4	117	2.6	3.6	4,500	2,200	950	19	99	99	156	
157	" 4	16:22	335	100	70	410	150	64	12	1.49 2.65	3.55	0.18	5,300	490	9.2	119	2.6	4.0	4,500	2,200	950	14	99	100	157	
158	" 4	20:06	330	100	70	410	150	64	12	1.49 2.68	3.07	0.18	4,600	529	11.5	118	2.6	4.0	4,500	2,200	950	17	99	100	158	
159	" 4	23:21	325	100	70	410	150	64	12	1.49 2.87	3.83	0.18	5,750	462	8.0	119	2.5	4.1	4,500	2,200	950	11	99	100	159	
160	" 5	3:22	320	85	73	440	120	73	12	1.51 2.98	4.12	0.18	6,200	532	8.6	120	2.5	4.4	3,900	2,100	510	18	99	100	160	
161	" 5	7:40	325	85	74	440	120	73	12	1.49 3.32	2.75	0.16	4,100	481	11.7	118	2.5	3.9	3,900	2,100	510	9	100	100	161	
162	" 5	10:35	325	100	69	440	120	73	12	1.51 4.05	6.47	0.16	9,700	509	5.2	122	2.4	4.6	3,900	2,100	510	5	100	100	162	
163	" 5	17:13	320	100	69	440	120	73	11	1.49 3.96	7.53	0.18	11,300	548	4.8	122	2.6	4.9	3,900	2,100	400	40	98	99	163	
164	" 6	00:56	315	100	68	440	120	73	12	1.50 4.04	6.18	0.18	9,300	533	5.7	122	2.5	5.0	3,900	2,100	350	9	100	100	164	
165	" 6	7:18	310	80	74	410	95	77	12	1.50 3.95	3.58	0.20	5,400	469	8.7	118	2.6	4.4	3,200	1,900	350	...	.....	.....	165	
166	" 6	11:05	305	80	74	410	95	77	12	1.50 3.60	8.10	0.18	12,200	518	4.2	122	2.4	5.4	3,200	1,900	350	14	99	100	166	
167	" 6	19:22	300	80	73	410	95	77	12	1.49 4.23	10.58	0.18	15,850	476	3.0	123	2.6	6.4	3,200	1,900	350	5	100	100	167	

168	Apr.	7	6:08	295	75	75	380	90	76	12	1.51 4.09	8.50	0.20	12,750	566	4.4	122	2.6	6.0	3,200	1,900	375	8	100	100	168	
169	"	7	14:50	290	75	74	380	90	76	12	1.51 3.89	7.42	0.18	11,150	528	4.7	122	2.6	5.8	3,200	2,000	375	18	99	100	169	
170	"	7	22:26	290	75	74	380	90	76	12	1.49 3.89	6.22	0.18	9,300	525	5.6	121	2.5	5.8	3,200	2,000	300	1	100	100	170	
171	"	8	4:50	285	40	86	420	60	86	12	1.51 3.87	5.68	0.16	8,950	491	5.5	121	2.5	5.6	4,800	2,800	250	4	100	100	171	
172	"	8	10:38	285	40	86	420	60	86	12	1.44 3.86	7.43	0.16	11,200	506	4.5	122	2.5	5.7	4,300	2,800	170	5	100	100	172	
173	"	8	18:15	280	40	86	420	60	86	12	1.00 3.96	11.15	0.18	16,700	514	8.1	128	2.5	6.5	4,300	2,800	250	5	100	100	173	
174	"	9	5:35	275	110	60	370	140	62	12	1.02 4.07	3.80	0.18	5,700	544	9.5	119	2.5	4.2	5,000	1,900	475	13	99	100	174	
175	"	9	8:34	275	110	60	370	140	62	12	0.99 3.91	3.30	0.18	4,950	514	10.4	119	2.6	4.2	5,000	1,900	475	......	......	.....	175	
176	"	9	12:03	275	110	60	370	140	62	12	0.76 3.51	3.96	0.16	5,950	480	8.1	120	2.6	4.2	5,000	1,900	475	13	99	99	176	
177	"	9	16:12	275	110	60	370	140	62	12	0.77 3.59	15.22	0.18	22,800	584	2.5	123	2.6	7.4	5,000	1,900	475	8	99	99	177	
178	"	10	7:36	275	65	76	400	85	79	12	0.76 3.65	10.85	0.16	16,250	495	3.0	123	2.6	5.7	4,700	1,400	475	14	99	99	178	
179	"	10	18:37	250	65	74	400	85	79	12	0.48 3.66	10.48	0.27	15,700	750	4.8	122	2.5	5.5	4,700	1,400	475	18	99	99	179	
180	May	3	9:10	460	35	92	450	75	83	6	5.08	21.28	0.18	31,900	576	1.8	123	2.6	6.5	2,800	4,100	625	210	95	93	180	New sand.
181	"	4	6:38	460	35	92	510	75	85	6	5.22	21.02	0.18	31,500	589	1.9	124	2.6	6.6	3,400	2,700	475	140	95	96	181	
182	"	5	3:50	460	50	91	510	75	85	6	4.14	11.42	0.18	17,050	556	3.3	123	2.6	4.7	2,100	1,600	425	150	91	93	182	
183	"	5	15:26	440	50	91	510	75	85	6	4.11	15.90	0.18	23,800	537	2.2	124	2.7	5.5	2,100	1,600	400	150	91	93	183	
184	"	6	7:31	420	45	91	480	70	85	6	4.11	19.93	0.16	29,900	556	1.9	124	2.7	5.5	1,600	1,600	275	210	87	87	184	
185	"	7	3:37	375	40	91	450	85	81	6	4.61	21.55	0.18	32,300	578	1.8	124	2.6	5.7	1,500	1,600	340	140	91	91	185	
186	"	8	1:21	370	60	84	430	50	89	6	5.00	21.16	0.18	36,200	563	1.6	124	2.6	5.5	2,600	1,900	250	130	93	95	186	
187	"	9	1:42	365	75	80	420	100	76	6	4.54	16.40	0.16	24,600	549	2.2	124	2.6	5.7	2,200	2,000	400	55	97	97	187	
188	"	9	18:16	365	75	80	420	100	76	6	3.12	12.13	0.18	18,150	579	3.2	124	2.5	5.4	2,200	2,000	525	480	76	78	188	
189	"	10	6:35	365	70	81	430	140	67	6	3.05	1.75	9.16	2,600	386	14.8	112	2.6	2.9	2,100	1,300	525	300	75	85	189	Stopped before end
190	"	10	14:00	365	70	81	430	140	67	3	4.07	4.65	0.16	6,950	547	6.2	121	2.7	8.8	2,100	1,300	525	......	.....	......	190	[of run to change
191	"	10	18:49	365	70	81	430	140	67	3	4.07	5.77	0.16	8,650	466	5.4	121	2.7	3.8	2,100	1,300	525	450	65	79	191	period of Coagula-
192	"	11	00:45	360	70	81	430	140	67	3	4.09	5.16	0.18	7,750	480	7.9	121	2.6	3.8	2,500	1,300	560	......	......	.....	192	tion to 6 hours.
193	"	11	6:06	360	60	83	420	120	71	3	4.00	6.33	0.16	9,500	465	4.9	122	2.6	4.1	3,000	1,900	600	750	60	75	193	
194	"	11	16:00	350	60	83	420	120	71	6	0.49 4.70	13.55	0.18	20,300	547	2.7	123	2.6	6.7	3,500	1,900	500	190	90	95	194	
195	"	12	5:44	340	25	93	400	50	87	6	0.48 4.05	20.10	0.16	30,100	524	1.7	124	2.7	8.0	4,500	3,300	425	575	83	87	195	
196	"	13	3:15	330	26	92	400	60	85	6	0.24 4.07	17.35	0.18	26,000	489	1.9	124	2.6	7.4	8,000	1,300	350	400	68	87	196	
197	"	13	20:47	320	26	92	390	60	85	6	0.24 4.05	17.12	0.16	25,600	511	2.0	124	2.6	6.7	1,700	1,800	350	725	45	57	197	
198	"	15	13:23	255	26	90	330	50	85	12	0.48 4.09	21.68	0.16	32,500	515	1.6	124	2.6	8.9	1,800	1,300	1,100	170	88	91	198	Alternating with No. [4 on 12 hour period
199	"	17	8:42	245	45	82	290	70	76	12	0.48 3.89	21.53	0.15	32,300	567	1.7	124	2.6	10.2	2,200	1,800	275	150	89	93	199	of Coagulation.
200	"	18	5:25	240	60	75	270	75	72	12	0.45 2.45	19.13	0.18	28,700	562	2.0	124	2.5	8.5	1,000	....	275	100	......	90	200	

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head, Feet. Initial.	Loss of Head, Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
152	Apr. 4	2:19	360	100	72	410	150	64	12	1.51 3.36	3.80	0.18	5,700	528	9.2	119	2.5	4.2	4,500	2,200	950	12	100	100	152	
153	" 4	6:18	355	100	72	410	150	64	12	1.51 3.30	2.37	0.16	3,550	454	12.8	117	2.5	3.7	4,500	2,200	950	20	99	100	153	
154	" 4	8.50	350	100	71	410	150	64	12	1.48 3.31	2.75	0.16	4,100	486	11.7	118	2.6	3.8	4,500	2,200	950	12	100	100	154	
155	" 4	11:45	345	100	71	410	150	64	12	1.51 3.33	1.48	0.18	2,200	488	22.2	111	2.5	3.6	4,500	2,200	950	...	.....	.....	155	
156	" 4	13:25	340	100	70	410	150	64	12	1.49 2.68	2.77	0.18	4,150	472	11.4	117	2.6	3.6	4,500	2,200	950	19	99	99	156	
157	" 4	16:22	335	100	70	410	150	64	12	1.49 2.65	3.55	0.18	5,300	490	9.2	119	2.6	4.0	4,500	2,200	950	14	99	100	157	
158	" 4	20:06	330	100	70	410	150	64	12	1.49 2.68	3.07	0.18	4,600	529	11.5	118	2.6	4.0	4,500	2,200	950	17	99	100	158	
159	" 4	23:21	325	100	70	410	150	64	12	1.49 2.87	3.83	0.18	5,750	462	8.0	119	2.5	4.1	4,500	2,200	950	11	99	100	159	
160	" 5	3:22	320	85	73	440	120	73	12	1.51 2.98	4.12	0.18	6,200	532	8.6	120	2.5	4.4	3,900	2,100	510	13	99	100	160	
161	" 5	7:40	325	85	74	440	120	73	12	1.49 3.32	2.75	0.16	4,100	481	11.7	118	2.5	3.9	3,900	2,100	510	9	100	100	161	
162	" 5	10:35	325	100	69	440	120	73	12	1.51 4.05	6.47	0.16	9,700	509	5.2	122	2.4	4.6	3,900	2,100	510	5	100	100	162	
163	" 5	17:13	320	100	69	440	120	73	11	1.49 3.96	7.53	0.18	11,300	548	4.8	122	2.6	4.9	3,900	2,100	400	40	98	99	163	
164	" 6	00:56	315	100	68	440	120	73	12	1.50 4.04	6.18	0.18	9,300	533	5.7	122	2.5	5.0	3,900	2,100	350	9	100	100	164	
165	" 6	7:18	310	80	74	410	95	77	12	1.50 3.95	3.58	0.20	5,400	469	8.7	118	2.6	4.4	3,200	1,900	350	...	.....	.....	165	
166	" 6	11:05	305	80	74	410	95	77	12	1.50 3.60	8.10	0.18	12,200	518	4.2	122	2.4	5.4	3,200	1,900	350	14	99	100	166	
167	" 6	19:22	300	80	73	410	95	77	12	1.49 4.23	10.58	0.18	15,850	476	3.0	123	2.6	6.4	3,200	1,900	350	5	100	100	167	

168	Apr.	7	6:08	295	75	75	380	90	76	12	1.51 4.09	8.50	0.20	12,750	566	4.4	122	2.6	6.0	3,200	1,900	375	8	100	100	168	
169	"	7	14:50	290	75	74	380	90	76	12	1.51 3.89	7.42	0.18	11,150	528	4.7	122	2.6	5.8	3,200	2,000	375	18	99	100	169	
170	"	7	22:26	290	75	74	380	90	76	12	1.49 3.89	6.22	0.18	9,300	525	5.6	121	2.5	5.8	3,200	2,000	300	1	100	100	170	
171	"	8	4:50	285	40	86	420	60	86	12	1.51 3.87	5.63	0.16	8,950	491	5.5	121	2.5	5.6	4,300	2,800	250	4	100	100	171	
172	"	8	10:38	285	40	86	420	60	86	12	1.44 3.86	7.43	0.16	11,200	506	4.5	122	2.5	5.7	4,300	2,800	170	5	100	100	172	
173	"	8	18:15	280	40	86	420	60	86	12	1.00 3.96	11.15	0.18	16,700	514	8.1	123	2.5	6.5	4,300	2,600	250	5	100	100	173	
174	"	9	5:35	275	110	60	370	140	62	12	1.02 4.07	3.80	0.18	5,700	544	9.5	119	2.5	4.2	5,000	1,900	475	13	99	100	174	
175	"	9	8:34	275	110	60	370	140	62	12	0.99 3.91	3.30	0.18	4,950	514	10.4	119	2.6	4.2	5,000	1,900	475	......	......	.....	175	
176	"	9	12:03	275	110	60	370	140	62	12	0.76 3.51	3.96	0.16	5,950	480	8.1	120	2.6	4.2	5,000	1,900	475	13	99	99	176	
177	"	9	16:12	275	110	60	370	140	62	12	0.77 3.59	15.22	0.18	22,800	584	2.5	123	2.6	7.4	5,000	1,900	475	8	99	99	177	
178	"	10	7:36	275	65	76	400	85	79	12	0.76 3.65	10.85	0.16	16,250	495	3.0	123	2.6	5.7	4,700	1,400	475	14	99	99	178	
179	"	10	18:37	250	65	74	400	85	79	12	0.48 3.66	10.48	0.27	15,700	750	4.8	122	2.5	5.5	4,700	1,400	475	18	99	99	179	
180	May	3	9:10	460	35	92	450	75	83	6	5.08	21.28	0.18	31,900	576	1.8	123	2.6	6.5	2,800	4,100	625	210	95	93	180	New sand.
181	"	4	6:38	460	35	92	510	75	85	6	5.22	21.02	0.18	31,500	589	1.9	124	2.6	6.6	3,400	2,700	475	140	95	96	181	
182	"	5	3:50	460	50	91	510	75	85	6	4.14	11.42	0.18	17,050	556	3.3	123	2.6	4.7	2,100	1,600	425	150	91	93	182	
183	"	5	15:26	440	50	91	510	75	85	6	4.11	15.90	0.18	23,800	537	2.2	124	2.7	5.5	2,100	1,600	400	150	91	93	183	
184	"	6	7:31	420	45	91	480	70	85	6	4.11	19.93	0.16	29,900	556	1.9	124	2.7	5.5	1,600	1,600	275	210	87	87	184	
185	"	7	3:37	375	40	91	450	85	81	6	4.61	21.55	0.18	32,300	578	1.8	124	2.6	5.7	1,500	1,600	340	140	91	91	185	
186	"	8	1:21	370	60	84	430	50	89	6	5.00	24.16	0.18	36,200	563	1.6	124	2.6	5.5	2,600	1,900	250	130	93	95	186	
187	"	9	1:42	365	75	80	420	100	76	6	4.54	16.40	0.16	24,600	549	2.2	124	2.6	5.7	2,200	2,000	400	55	97	97	187	
188	"	9	18:16	365	75	80	420	100	76	6	3.12	12.13	0.18	18,150	579	3.2	124	2.5	5.4	2,200	2,000	525	480	76	78	188	
189	"	10	6:35	365	70	81	430	140	67	6	3.05	1.75	9.16	2,600	386	14.8	112	2.6	2.9	2,100	1,300	525	300	75	85	189	Stopped before end [of run to change period of Coagulation to 6 hours.
190	"	10	14:00	365	70	81	430	140	67	3	4.07	4.65	0.16	6,950	547	6.2	121	2.7	3.8	2,100	1,300	525	......	.....	......	190	
191	"	10	18:49	365	70	81	430	140	67	3	4.07	5.77	0.16	8,650	466	5.4	121	2.7	3.8	2,100	1,300	525	450	65	79	191	
192	"	11	00:45	360	70	81	430	140	67	3	4.09	5.16	0.18	7,750	480	7.9	121	2.6	3.8	2,500	1,300	560	......	......	.....	192	
193	"	11	6:06	360	60	83	420	120	71	3	4.00	6.33	0.16	9,500	465	4.9	122	2.6	4.1	3,000	1,900	600	750	60	75	193	
194	"	11	16:00	350	60	83	420	120	71	6	0.49 4.70	13.55	0.18	20,300	547	2.7	123	2.6	6.7	3,500	1,900	500	190	90	95	194	
195	"	12	5:44	340	25	93	400	50	87	6	0.48 4.05	20.10	0.16	30,100	524	1.7	124	2.7	8.0	4,500	3,300	425	575	83	87	195	
196	"	13	3:15	330	26	92	400	60	85	6	0.24 4.07	17.35	0.18	26,000	489	1.9	124	2.6	7.4	3,000	1,300	350	400	68	87	196	
197	"	13	20:47	320	26	92	390	60	85	6	0.24 4.05	17.12	0.16	25,600	511	2.0	124	2.6	6.7	1,700	1,300	350	725	45	57	197	
198	"	15	13:23	255	26	90	330	50	85	12	0.48 4.09	21.68	0.16	32,500	515	1.6	124	2.6	8.9	1,800	1,300	1,100	170	88	91	198	Alternating with No. [4 on 12 hour period of Coagulation.
199	"	17	8:42	245	45	82	290	70	76	12	0.48 3.89	21.53	0.15	32,300	567	1.7	124	2.6	10.2	2,200	1,800	275	150	89	93	199	
200	"	18	5:25	240	60	75	270	75	72	12	0.45 2.45	19.13	0.18	28,700	562	2.0	124	2.5	8.5	1,000	....	275	100	......	90	200	

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began.		Suspended Matter.			Silica Turbidity.			Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
	Date, 1900-1901.	Hour	Parts per Million. Subsided Water.	Parts per Million. Coagulated Water.	Per Cent. Removed.	Parts per Million. Subsided Water.	Parts per Million. Coagulated Water.	Per Cent. Removed.			Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
201	May 19	00:44	220	65	71	270	75	72	12	0.48 2.44	16.77	0.18	25,200	585	2.8	124	2.6	8.0	2,300	....	375	150	......	94	201	
202	" 19	17:41	220	75	66	260	80	69	12	0.48 2.45	16.98	0.18	25,400	519	2.0	124	2.5	8.0	1,700	1,400	375	130	91	93	202	
203	" 20	10:51	220	40	82	270	65	76	12	0.48 2.46	19.52	0.15	29,300	529	1.8	124	2.7	10.7	1,900	1,200	375	75	94	96	203	No. 4 Filter running as No. 3 Filter.
204	" 21	6:31	215	35	84	......	65	......	12	0.48 2.34	22.30	0.15	33,500	514	1.5	124	2.6	10.8	1,200	1,050	280	75	93	94	204	No. 4 Filter running as No. 3 Filter.
205	" 22	4:58	195	50	74	230	60	74	12	0.48 2.34	22.93	9.15	34.400	486	1.4	124	2.7	10.7	1,000	1,100	350	65	94	94	205	No. Filter running as No. 3 Filter.
206	" 23	3:51	180	55	70	210	70	67	12	0.49 2.32	26.05	0.20	39,100	623	1.6	124	2.6	10.1	1,100	900	275	65	93	94	206	No. 3 Filter running on its own basin.
207	" 24	5:06	175	100	43	190	130	32	6	0.48 2.32	9.42	0.18	14,150	513	3.6	123	2.5	6.9	1,200	1,150	275	70	94	94	207	
208	" 24	14:42	170	100	41	190	130	32	6	0.68 2.06	5.96	0.16	8,950	518	5.8	122	2.6	5.2	1,200	1,150	275	85	93	93	208	
209	" 24	20:50	165	100	39	180	130	28	6	0.98 2.05	9.72	0.18	14,550	527	3.6	123	2.4	7.5	1,800	8,000	....	250	97	81	209	
210	" 25	6:44	160	105	34	190	140	26	6	0.98 2.05	6.40	0.20	9,600	578	6.0	121	2.5	5.2	1,300	1,250	. ...	275	78	79	210	
211	" 25	13:20	150	105	30	200	140	30	6	1.48 2.06	5 15	0.18	7,700	521	6.8	121	2.5	4.9	1,300	1,350	....	......	....	......	211	
212	" 25	18:40	150	75	50	190	100	47	6	1.47 2.04	13.70	0.18	20,500	561	2.7	123	2.4	7.6	2,200	1,400	500	120	91	95	212	
213	" 26	8:33	160	60	63	190	80	58	6	1.47 2.05	3.65	0.20	5,450	596	10.9	118	2.5	3.6	2,200	1,600	600	200	88	91	213	
214	" 26	12:24	160	60	63	190	80	58	6	1.99 2.05	7.65	0.18	11,450	596	5.2	122	2.5	5.2	2,200	1,600	650	55	66	98	214	
215	" 27	4:00	170	40	77	200	75	63	12	0.49 2.00	11.23	0.20	16,800	541	3.2	123	2.6	7.3	2,500	2,000	1,000	160	92	94	215	
216	" 27	15:26	170	30	82	190	65	66	12	0.48 2.36	23.23	0.20	34 800	540	1.6	124	2.6	7.8	2,500	2,000	400	140	93	94	216	

219	"	31	7:23	160	50	69	200	55	73	12	[illegible] 2.48	30.72	0.20	46,000	593	1.3	124	2.6	10.8	1,500	650	[illegible]	[illegible]			
220	June	1	15:37	180	60	67	220	60	73	12	0.49 2.55	20.65	0.18	31,000	597	1.9	124	2.6	10.8	1 000	950	275	550	42	45	220
221	"	2	12:27	240	85	65	300	85	72	12	0.69 2.94	24.33	0.20	36,500	628	1.7	124	2.5	10 8	1,400	1,100	110	550	50	61	221
222	"	3	12:59	250	40	84	280	65	77	12	0.98 3.15	19.54	0.18	29,300	597	2.0	124	2.5	10.8	3,000	700	300	850	......	72	222
223	"	4	8:42	250	35	86	270	60	78	12	0.97 3.20	19.75	0.16	29,600	525	1.8	124	2.5	10.8	1,400	1,700	850	......	......	......	223
224	"	5	5:38	245	40	87	280	60	79	12	0.98 3.09	29.18	0.20	43,800	666	1.5	124	2.6	10.8	2,500	2,500	650	......	......	......	224
225	"	6	11:01	240	40	87	260	55	79	12	1.46 2.66	21.16	0.20	31,700	574	1.8	124	2.5	10.8	3,400	1,900	750	700	63	79	225
226	"	7	8:23	215	30	86	270	45	83	12	1.99 3.43	32.60	0.20	49 000	612	1.2	124	2.5	10.7	2,900	1,400	350	850	39	71	226
227	"	8	17:11	195	30	85	270	60	78	6	1.98 3.05	23.82	0.20	35,800	615	1.7	124	2.5	10.3	3,000	1,900	240	170	91	94	227
228	"	9	17:12	195	50	74	300	80	73	6	1.98 3.03	27.45	0.20	41,200	555	1.3	124	2.5	10.1	2,700	1,100	325	50	95	98	228
229	"	10	20:51	195	40	79	280	65	77	6	1.49 2.95	26.45	0.20	39,700	545	1.4	124	2.6	10.0	2,500	1,400	325	75	95	97	229
230	"	11	23:28	200	......	...	280	65	77	6	0.49 2.90	32.80	0.20	49,200	622	1.3	121	2.6	9.0	2,800	850	300	75	91	97	230
231	"	13	7:28	200	45	77	290	65	78	6	0.49 2.42	24.06	0.20	36,000	525	1.4	124	2.5	9.3	2 000	1,900	375	65	97	97	231	Shut down to change sand at 7:45.
232	"	14	15:35	190	25	87	285	60	78	6	0.50 2.46	18.60	0.18	27,900	....	......	124	2.7	10.8	1,100	....	350	100	......	91	232	New sand: shut down at 10:00.
233	"	15	18:32	200	25	88	300	50	83	6	0.48 2.51	9.70	0.18	14,500	483	3.8	123	4.1	10.5	1,200	800	....	......	......	......	233	New sand.
234	"	16	4 25	210	30	86	300	75	75	6	0.49 2.45	5.27	0.16	7,900	447	5.6	122	3.4	10.8	....	....	....	100	......	......	234
235	"	16	9:51	210	40	81	300	75	75	6	0.48 2.51	6.21	0.16	9,300	509	5.5	122	3.4	10.8	1,900	....	275	85	......	96	235
236	"	16	16:04	220	50	77	300	75	75	6	0.49 2.48	5.61	0.18	8,400	489	5.8	122	3.2	10.8	1,900	....	180	48	......	97	236
237	"	16	21:52	220	50	77	300	70	77	6	0.49 2.51	5.55	0.18	8,750	462	5.3	122	3.3	10.8	1,400	....	200	70	......	95	237
238	"	17	3:54	220	60	73	300	70	77	6	0.49 2.48	6.08	0.16	9,150	440	4.8	122	3.3	10.1	1,300	1,100	170	95	91	93	238
239	"	17	10:09	225	60	73	300	70	77	6	0.48 2.50	6.60	0.16	9,900	510	5.1	122	3.3	10.8	1,300	1 100	170	85	92	93	239
240	"	17	16:55	230	75	67	300	80	73	6	0.38 2.43	7.52	0.18	11,300	457	4.0	122	3.2	10.8	800	950	350	25	97	97	240
241	"	18	00.47	235	70	70	280	70	75	6	0.38 2 51	5.20	0.18	7,800	432	5.5	122	3.3	10.0	1,100	1,100	373	50	95	95	241
242	"	18	6:09	235	70	70	270	70	74	6	0.38 2.49	7.97	0.16	11,950	539	4.5	122	3.4	10.8	1,200	1,300	450	70	95	94	242

TABLE LVII.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent Removed.	Period of Coagulation, Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
243	June 18	14:17	240	85	65	240	100	58	6	0.36 2.51	6.88	0.16	10,300	428	4.2	122	3.2	10.8	650	650	350	65	90	90	243	
244	" 18	21:20	250	50	80	250	60	76	6	0.31 2.40	6.27	0.16	9,400	375	4.0	122	3.4	10.8	850	650	95	47	93	95	244	
245	" 19	3:46	250	50	80	270	60	78	6	0.31 2.22	6.20	0.18	9,300	525	5.6	122	3.4	10.8	1,100	700	230	55	92	95	245	
246	" 19	10:29	225	50	78	290	65	78	6	0.40 2.21	6.65	0.16	10,000	529	5.3	122	3.2	10.8	1,000	700	475	55	92	95	246	
247	" 19	17:19	220	70	68	260	95	63	6	0.48 2.22	5.98	0.16	8,900	443	5.0	122	3.2	10.8	1,200	1,200	350	14	99	99	247	
248	" 19	23:25	220	40	82	260	55	79	6	0.48 2.30	6.00	0.20	9,000	443	4.9	122	3.3	10.8	1,600	1,200	200	50	97	97	248	
249	" 20	5:34	200	50	75	260	70	73	6	0.49 2.32	6.41	0.16	9,600	508	5.2	122	3.3	10.8	1,100	1,100	325	50	95	95	249	
250	" 20	12:25	185	55	70	240	80	67	6	0.67 2.34	7.54	0.18	11,300	455	4.0	122	3.3	10.8	1,000	1,000	500	120	88	88	250	
251	" 20	20:30	185	60	68	240	85	65	6	0.67 2.28	9.52	0.18	14,260	502	3.5	123	3.3	10.8	1,000	1,000	210	85	92	92	251	
252	" 21	6:22	190	70	63	260	100	62	6	1.01 2.16	7.41	0.18	11,100	510	4.6	122	3.3	10.8	1,000	1,000	400	60	94	94	252	
253	" 21	14:14	190	60	68	240	95	60	6	1.00 2.23	6.22	0.16	9,350	421	4.5	122	3.1	10.8	750	425	80	......	......	......	253	
• 254	" 21	20:46	190	......	......	240	90	63	6	1.00 2.25	6.36	0.18	9,550	495	5.2	122	3.3	10.8	900	850	300	......	......	—	254	
255	" 22	3:33	190	50	74	260	80	69	6	0.31 2.22	9.17	0.18	13,700	445	3.2	123	3.3	18.7	1,700	1,300	425	......	......	......	255	

260	"	24	2:31	190	40	79	270	90	67	6	[illegible] 2.84	10.85	0.16	16,270	545	5.5	125	3.3	10.7	....	....	....	......	......	......	260	
261	"	24	13:31	195	40	80	290	85	70	6	0.72 2.82	6.90	0.16	10,850	447	4.3	122	3.3	10.7	....	....	....	......	......	......	261	
262	"	24	20:35	190	40	79	280	80	71	6	0.67 2.89	9.52	0.16	14,300	465	3.2	123	3.2	10.8	2,000	....	600	......	......	......	262	
263	"	25	6:16	190	30	84	300	65	78	6	1.01 2.84	10.88	0.16	16,300	352	2.1	123	3.3	10.7	2,600	1,200	800	17	99	99	263	
264	"	25	17:19	195	35	82	260	75	71	6	2.98	14.68	0.16	22,000	499	2.3	123	3.3	10.8	2,200	1,700	600	95	94	96	264	
265	"	26	14:24	190	30	84	240	60	75	6	3.08	12.46	0.16	18,700	471	2.5	123	3.2	10.8	2,200	1,800	550	95	95	96	265	
266	"	27	3:22	180	30	88	300	60	80	6	2.94	11.50	0.16	17,250	542	3.1	123	3.3	10.8	2,000	1,600	1,200	70	96	97	266	
267	"	27	20:00	210	35	83	300	75	75	12	0.19 2.88	17.75	0.16	26,600	484	1.8	124	3.3	10.8	2,100	1,700	1,000	90	95	96	267	
268	"	28	13:55	210	20	90	300	30	90	12	0.19 2.82	15.67	0.16	23,500	420	1.8	123	3.3	10.8	2,000	1,700	350	......	......	......	268	
269	"	29	5:45	220	25	89	325	40	88	12	0.40 2.73	17.48	0.16	26,200	449	1.7	124	3.3	10.8	1,400	1,300	300	....	......	..	269	
270	"	29	23:24	230	20	91	350	35	90	12	0.61 2.96	19.28	0.16	28,900	439	1.5	124	3.3	10.7	1,400	900	325	17	81	88	270	
271	"	30	18:51	240	20	92	350	35	90	12	0.57 2.92	19.55	0.16	29,300	467	1.6	124	3.4	10.8	1,300	850	600	......	......	......	271	
272	July	1	14:34	260	35	87	350	45	87	12	0.80 2.92	19.75	0.16	29,600	450	1.5	124	3.3	10.7	1,700	900	230	......	......	......	272	
273	"	2	9:29	275	40	85	375	50	87	12	0.79 2.97	20.02	0.16	30,000	452	1.5	124	3.3	10.8	2,600	1,300	1,200	......	......	......	273	
274	"	3	5:40	290	40	86	375	50	87	12	0.19 2.99	18.90	0.16	28,400	503	1.8	124	3.2	10.8	1,500	1,600	325	55	97	96	274	
275	"	4	00:44	290	40	86	350	50	86	12	0.19 3.26	20.87	0.16	31,400	500	1.6	124	3.3	10.8	1,700	1,300	240	27	98	98	275	
276	"	7	00:13	275	45	84	400	65	84	6	3.60	13.58	0.16	20,400	462	2.3	123	3.1	10.8	1,600	1,300	300	31	98	98	276	
277	"	7	13:59	300	50	83	400	65	84	6	3.85	12.60	0.16	18,900	519	2.7	123	3.3	10.8	2,200	1,300	180	40	97	98	277	
278	"	8	2:45	320	50	84	400	60	85	6	3.89	12.52	0.17	18,800	544	2.8	123	3.2	10.6	1,200	800	180	65	92	95	278	
279	"	8	15:28	320	50	84	400	60	85	6	3.96	12.63	0.16	18,900	537	2.8	123	3.3	10.7	1,200	750	300	55	93	95	279	
280	"	9	4:16	320	55	83	400	65	84	6	3.96	12.07	0.14	18,200	569	3.1	123	3.1	10.7	1,700	1,100	350	70	94	96	280	Beginning with run 280 even numbered runs washed without air.
281	"	9	16:28	320	55	83	425	65	85	6	3.94	14.16	0.17	21,200	521	2.4	123	3.3	10.7	2,000	1,000	250	70	93	97	281	+ Air.
282	"	10	6:49	350	55	84	450	65	86	6	4.08	12.97	0.14	19,500	474	2.4	123	3.2	10.8	1,700	1,000	230	90	91	95	282	— "
283	"	10	19:55	360	50	86	450	60	87	6	4.18	13.95	0.16	21,000	454	2.2	123	3.1	10.7	1,800	1,100	350	90	92	95	283	+ "
284	"	11	9:02	330	40	88	425	80	81	6	4.19	16.40	0.14	24,600	532	2.2	124	3.2	10.8	1,600	1,200	400	70	94	96	284	— "
285	"	12	1:34	300	40	87	450	80	82	12	5.54 4.05	4.43	0.15	6,650	408	6.1	121	3.1	10.8	1,900	1,100	200	80	93	96	285	+ "
286	"	12	6:09	310	20	94	450	40	91	12	5.53 3.60	4.98	0.13	7,500	315	4.2	122	3.2	10.7	1,900	1,100	65	95	91	95	286	— "
287	"	12	11:15	330	20	94	450	40	91	12	0.48 3.64	21.20	0.16	31,800	464	1.5	124	3.1	10.7	1,600	1,300	230	95	93	94	287	+ "
288	"	13	8:37	350	32	91	450	50	89	12	0.47 3.65	17.08	0.16	23,400	471	2.0	124	3.2	10.7	1,600	1,600	80	95	94	94	288	— "
289	"	14	1:51	350	30	91	400	45	89	12	0.47 3.66	14.63	0.15	22,000	437	2.0	124	3.1	10.7	1,500	1,200	140	95	92	94	289	+ "

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
290	July 14	16:33	310	30	90	400	45	89	12	0.47 3.55	11.38	0.16	17,000	480	2.8	124	3.2	10.8	1,500	1,200	160	80	93	95	290	— Air.
291	" 15	3:54	310	28	91	400	45	89	12	0.48 3.33	12.88	0.14	19,300	403	2.1	124	3.1	10.7	1,500	1,000	250	75	93	95	291	+ "
292	" 15	16:56	300	27	91	400	40	90	12	0.47 3.38	15.28	0.13	22,900	394	1.7	124	3.1	10.7	1,800	1,200	200	55	95	97	292	— "
293	" 16	8:21	290	26	91	350	40	89	12	0.45 3.41	19.42	0.16	29.100	416	1.4	124	3.2	10.7	2,700	1.100	65	65	94	98	293	Run broken into. + Air.
294	" 17	14:20	300	29	90	400	35	91	12	0.49 3.33	19.43	0.13	29,200	390	1.3	124	3.2	10.7	1,800	1,500	250	85	94	95	294	Run broken into. — Air.
295	" 18	14:35	350	29	92	450	35	92	12	0.19 3.58	20.18	0.18	30,250	525	1.7	124	3.2	10.8	2,100	1,800	325	90	95	96	295	Run broken into. + Air.
296	" 19	10:59	350	40	89	425	40	91	12	0.19 3.74	16.10	0.15	24,200	547	2.3	124	3.3	10.7	2,000	1,400	350	90	94	96	296	— "
297	" 21	10:42	250	.....	....	275	95	66	6	3.20	14.75	0.16	22,100	542	2.5	124	3.2	10.8	1,500	1,900	500	90	95	94	297	+ "
298	" 22	1:27	200	.....	......	225	110	51	6	3.20	12.82	0.15	19.200	561	2.9	123	3.2	10.7	1,400	750	400	60	92	96	298	— "
299	" 22	14:25	160	......	......	180	90	50	6	3.19	4.40	0.15	6.600	506	7.7	121	3.2	10.8	2,300	800	120	55	93	98	299	+ "
300	" 23	6:01	140	......	......	170	80	53	6	3.33	14.22	0.13	21,300	536	2.5	124	3.4	10 7	2,500	700	375	65	91	97	300	— "
301	" 23	20:22	125	......	......	170	90	47	6	2.93	10.42	0.18	15,600	540	3.5	123	3.5	10.8	1,700	700	550	265	62	84	301	+ "
302	" 24	6:58	130		......	180	75	58	6	2.75	13.67	0.13	20,500	502	2.5	124	3.2	10.8	2,100	1,000	450	275	73	87	302	— "
303	" 24	20:46	140	......	......	180	85	53	6	2.90	15.35	0.20	23,000	546	2.4	123	3.2	10.8	2,100	1,100	....	170	85	92	303	+ "
304	" 25	12:19	130	......	......	160	95	41	6	2.69	14.73	0.13	22,200	523	2.4	124	3.1	10.9	1,400	1,100	550	250	77	82	304	— "
305	" 26	8:11	130	.	......	190	100	47	6	2.50	14.35	0.18	21,600	546	2.5	123	3.2	10.9	1,600	650	500	220	66	86	305	+ Beginning with run 306 all washes with air.
306	" 26	17:43	140	......	......	200	95	53	6	2.88	16.42	0.18	24,500	519	2.1	124	3.2	10.9	3,600	550	400	150	73	96	306	
307	" 27	10:19	150	......	......	200	85	58	6	3.06	14.40	0.16	21,600	497	2.3	124	3.2	11.0	1,000	500	250	650	......	35	307	
308	" 28	20:41	160			200	75	63	6	3.23	16.35	0.18	24,500	523	2.1	124	3.0	10.7	1,400	1,100	650	150	86	89	308	

314	"	3	12:49	115	......	......	150	22	85	6	[illegible] 1.60	12.28	0.16	18,400	398	2.2	123	3.1	10.8	650	1,400	400	425	70	85	314	
315	"	4	1:16	110	......	....	130	22	83	6	0.36 1.60	13.27	0.16	19,900	574	2.9	122	3.1	10.8	700	....	230	350	.....	50	315	
316	"	4	21:37	100	......	......	130	25	81	6	0.38 1.62	5.85	0.15	8,800	369	4.2	123	3.1	10.8	....	650	....	......	......	......	316	
317	"	5	3:37	100	.....	......	120	23	81	6	0.38 1.61	10.65	0.16	16,000	465	2.9	123	3.1	10.8	....	650	....	....	...	......	317	
318	"	5	18:52	95	......	......	120	30	75	6	0.39 1.57	10.87	0.18	16,300	363	2.2	123	3.2	10.8	....	....	... ...	......	......	.....	318	
319	"	6	5:53	95	......	... ..	120	30	75	6	0.39 1.53	14.35	0.16	21,500	401	1.9	123	3.2	10.9	1,200	700	425	110	84	91	319	
320	"	6	20:24	95	......	......	110	28	75	6	0.38 1.51	11.08	0.16	16,600	480	2.9	123	3.2	10.8	800	700	375	150	79	81	320	
321	"	7	7:29	95	.....	......	120	30	75	6	0.83 1.53	11.77	0.15	17,600	420	2.4	124	2.9	10.7	1,500	850	300	140	84	91	321	
322	"	7	19:24	95	......	......	90	30	67	6	0.38 1.58	13.38	0.16	20,000	480	2.4	123	3.0	10.8	900	1,000	550	210	79	77	322	
323	"	8	8:57	85	.....	......	110	20	82	6	0.88 1.61	10.90	0.16	16,300	548	3.4	128	2.9	10.7	850	1,000	275	130	87	85	323	
324	"	8	20:01	75	......	......	110	35	68	6	0.38 1.51	11.08	0.16	16,600	479	2.9	123	3.0	10.8	475	700	500	500	29	......	324	
325	'	9	17:35	75	......	......	100	28	72	6	0.38 1.35	2.70	0.16	4,000	413	10.3	118	5.9	10.7	450	700	500	150	79	66	325	New sand.
326	"	9	20:27	75	......	......	100	28	72	6	0.38 1.35	3.75	0.16	5,600	375	6.7	120	5.3	10.8	1,400	800	325	700	12	50	326	
327	"	10	00:22	75	.....	....	100	23	72	6	0.38 1.35	4.75	0.16	7,100	374	5.3	121	5.2	10.8	....	....	....	......	......	......	327	
328	"	10	5:17	75	.....	......	95	27	72	6	0.37 1.40	3.97	0.15	5,900	318	5.4	120	5.4	10.8	......	....	....	......	......	.....	328	
329	"	10	9:24	75	......	......	95	27	72	6	0.37 1.40	3.45	0.15	5,200	386	7.4	120	5.8	10.8	1,900	450	1,300	210	58	89	329	
330	"	10	13:00	75	......	......	95	27	72	6	0.37 1.40	4.78	0.15	7,200	394	5.5	121	4.7	10.8	1,900	450	1,300	140	69	93	330	
331	"	10	22:00	75	......	.....	95	27	72	6	0.38 1.40	5.53	0.15	8,300	371	4.5	122	5.1	10.7	1,000	600	325	95	84	91	331	
332	"	11	3:41	75	......	......	100	25	75	6	0.37 1.39	8.23	0.16	12,400	502	4.1	123	4.8	10.8	700	800	250	60	93	91	332	
333	"	11	12:05	75	......	......	100	25	75	6	0.38 1.39	5.13	0.15	7,700	420	5.4	121	4.4	10.8	900	850	250	80	91	91	333	
334	"	11	22:00	75	.....	......	100	25	75	6	0.37 1.39	4.80	0.13	7,200	303	4.2	124	4.7	10.7	1,900	900	275	100	89	95	334	
335	"	12	2:56	75	......	......	110	65	41	6	0.38 1.39	5.13	0.15	7,700	427	5.5	121	4.7	10.8	1,200	1,000	325	90	91	93	335	
336	"	12	8:13	75	......	......	110	65	41	6	0.38 1.39	5.43	0.15	8,100	415	5.1	122	4.4	10.8	475	1,000	350	90	91	81	336	
337	"	12	21:30	80	......	......	110	65	41	0.25	2.05	1.78	0.15	2 700	394	14.6	115	4.8	10.7	475	500	300	25	95	95	337	
338	"	12	22:36	85	......	......	100	95	5	0.25	2.05	2.63	0.15	3,900	382	9.8	118	4.6	10.7	475	500	300	28	94	94	338	
339	"	13	2:13	85	......	.....	100	95	5	0.25	2.10	2.15	0.15	3,200	382	11.9	117	4.6	10.7	475	500	300	46	91	91	339	
340	"	13	4:31	85	......	......	100	95	5	0.25	2.10	2.68	0.15	3,900	427	11.0	118	4.6	10.7	275	350	200	23	93	92	340	

TABLE LVII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 3.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
341	Aug 13	7:18	80	......	......	100	95	5	0.25	2.10	2.32	0.15	3,500	382	10.9	117	4.4	10.8	275	350	200	29	92	89	341	
342	" 13	9:46	75	......	......	100	95	5	0.25	2.10	2.03	0.15	3,000	417	13.9	116	4.4	10.8	275	300	230	37	88	88	342	
343	" 13	11:57	75	......	......	100	95	5	0.25	2.10	2.17	0.15	3,300	490	11.8	117	4.4	10.8	275	325	240	23	93	92	343	
344	" 13	14:16	75	......	......	100	95	5	0.25	2.10	2.08	0.15	3,100	397	12.8	117	4.4	10.8	275	325	250	39	88	86	344	
345	" 13	16:30	75	......	......	100	95	5	0.25	2.10	1.98	0.15	2,900	349	12.0	116	4.4	10.7	275	325	275	37	89	87	345	
346	" 13	18:35	75	......	......	100	95	5	6.25	2.10	2.01	0.13	3,000	326	10.9	117	4.4	10.7	210	325	325	23	93	89	346	
347	" 13	20:45	70	......	......	100	95	5	0.25	2.10	2.35	0.13	3,500	311	8.9	118	4.4	10.7	150	325	400	39	88	74	347	
348	" 13	23:14	65	......	......	100	95	5	0.25	2.10	2.30	0.13	3,500	388	11.0	118	4.4	10.7	150	325	400	34	90	77	348	
349	" 14	1:40	65	......	......	85	55	35	0.25	2.10	2.43	0.13	3,700	327	8.8	100	4.4	10.7	150	350	400	27	92	82	349	
350	" 14	4:14	65	......	......	85	55	35	0.25	2.10	2.12	0.15	3,200	390	12.2	117	4.4	10.7	325	350	375	95	73	71	350	
351	" 14	6:30	65	......	......	85	55	35	0.25	2.10	2.03	0.15	3,050	371	12.0	116	4.4	10.7	325	350	375	46	87	86	351	
352	" 14	8:41	65	......	......	85	55	35	0.25	2.10	2.02	0.15	3,050	371	12.0	116	4.4	10.7	325	350	375	40	89	88	352	
353	" 14	10:51	65	......	......	85	55	35	0.25	2.10	2.06	0.15	3,100	407	13.1	116	4.4	10.7	300	325	300	32	90	89	353	
354	" 14	13:04	65	......	......	85	55	35	0.25	2.10	2.12	0.15	3,200	427	13.3	117	4.3	10.9	300	325	250	18	94	94	354	
355	" 14	16:04	65	......	......	85	55	35	0.25	2.10	2.48	0.15	3,700	446	12.0	118	4.5	10.9	300	325	250	6	98	98	355	
356	" 14	18:40	65	......	......	85	55	35	0.25	2.10	2.40	0.15	3,600	345	9.6	117	4.4	10.8	350	325	170	22	93	94	356	
357	" 14	21:14	65	......	......	85	55	35	6	1.39	5.80	0.15	8,700	406	4.7	122	4.4	10.8	400	425	95	19	96	95	357	
358	" 16	13:00	100	......	......	130	110	15	0.25	2.30	1.72	0.23	2,600	447	17.2	110	5.1	10.7	475	200	300	75	63	84	358	
359	" 16	14:57	100	......	......	130	110	15	0.25	2.30	1.98	0.20	3,000	369	12.3	113	4.5	10.8	550	130	650	75	42	86	359	
360	" 16	17:08	100	......	......	130	110	15	0.25	2.30	2.13	0.15	3,200	352	11.0	117	4.4	10.8	550	130	650	170	......	69	360	
361	" 16	19:25	100	......	......	130	110	15	0.25	2.30	2.55	0.13	3,800	394	10.4	119	4.4	10.8	550	130	1,200	90	31	84	361	
362	" 16	22:06	100	......	......	130	110	15	0.25	2.30	2.20	0.13	3,300	368	11.2	118	4.4	10.8	550	600	1,700	150	75	73	362	
363	" 17	00:26	100	......	......	95	90	5	0.25	2.30	2.18	0.13	3,300	376	11.4	118	4.4	10.8	550	600	1,700	130	78	76	363	
364	" 17	2:45	90	......	......	95	90	5	0.25	2.20	2.45	0.13	3,700	352	9.5	119	4.4	10.8	1,100	1,100	1,500	230	79	79	364	
365	" 17	5:20	85	......	......	95	90	5	0.25	2.20	2.48	0.15	3,700	597	16.2	118	4.4	10.8	1,600	1,100	1,400	325	70	80	365	
366	" 17	7:58	75	......	......	95	90	5	0.25	2.20	2.05	0.27	3,100	354	11.4	110	4.1	10.8	1,600	1,100	1,400	325	70	80	266	

TABLE LVIII.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
1	Dec. 19	16:59	....	....	....	....	....	....	6	3.66	15.60	0.35	23,400	651	2.8	122	....	....	1,100	....	2 500	....	....	....	1	
2	" 20	8:56	....	....	....	....	....	....	6	3.14	6.17	0.30	9,250	666	7.2	119	....	....	800	....	2,000	....	....		2	
3	" 20	15:24	....	....	....	....	....	....	6	2.97	6.10	0.23	9,150	628	6.9	120	....	....	800		2 000	....	....	....	3	
4	" 20	21:44	....	....	....	....		....	6	2.93	7.60	0.23	11,400	740	6.5	121	....	....	800	....	2,000	....	....	....	4	
5	" 22	7:33	....	....	....	290	....	....	6	3.09	5.63	0.27	8,450	681	8.0	119	....	....	2,400	....	2,500	....	....	....	5	
6	" 22	13:27	....	....	....	290	....	....	6	3.15	7.42	0.25	11.125	703	6.3	121		....	2,400	....	3,000	....	....	....	6	
7	" 22	21 07	....	....		290		....	6	2.93	9.23	0.30	13,850	546	3.9	121	....	....	2,400	....	3,800	....	....	....	7	
8	" 23	6:39	....	....	....	270	....	....	6	2.70	5.08	0.27	7 625	703	9.2	119	....	....	1 800	....	3,700	....	....	....	8	
9	" 23	12:00	....	....	....	270	....	....	6	2.99	6.20	0.23	9,300	621	6.7	121	....	....	1,800	....	....	....	....	....	9	
10	" 23	18:26	....	....	....	270	....	....	6	3.13	8.15	0.35	12,225	755	6.2	120	....	....	1,800	....	2,000	....	....	....	10	
11	" 24	2:56	....	....		250	....	....	6	2.82	4.68	0.35	7,025	568	8.1	116	....	....	1,200	....	1,500	....	....	....	11	
12	" 24	7:58	....	....	....	250	....	....	6	2.87	4.68	0.22	8,175	598	7.3	120	....	....	1,200	....	1,400	....	....	....	12	
13	" 24	13:38	....	....	....	250	....	....	6	2.81	6.67	0.27	10.000	688	6.9	120	....	....	1,200	....	1,300	....	....	....	13	
14	" 24	20:34	....	....	....	250	....	....	6	3.02	6.77	0.35	10,150	673	6.6	119	....	....	1,200	....	1,300	....	....	....	14	
15	" 25	3:41	....	....	....	250	....	....	6	2.52	7.48	0.30	11 225	658	5.9	120	....	....	1,500	....	1,500	....	....	....	15	
16	" 25	11:28	....	....	....	250	....	....	6	2.48	4.72	0.20	7,075	703	9.9	120	....	....	1,500	....	1,700	....	....	....	16	
17	" 25	16:23	....	....	....	250	....	....	6	3.07	8.23	0.33	12,325	606	4.9	120	....	....	1,800	....	1,700	....	....	....	17	
18	" 26	00:57	180	....	....	230	....	....	6	2.60	6.25	0.33	9,375	628	6.7	119	....	....	1,800	....	1,500	....	....	....	18	
19	" 26	7:32	170	....	....	210	....	....	6	2.25	5.17	0.25	7,750	636	8.2	120	....	....	1 800	....	1,000	....	....	....	19	
20	" 26	12:57	170	....	....	210	....	....	6	2.49	4.70	0.27	7,050	748	10.6	118	....	....	1,800	....	1,000	....	....	....	20	
21	" 26	17:55	170	....	....	210	....	....	6	2.94	7.40	0.33	11.600	673	5.8	120	....	....	1,800	....	1,000	....	....	....	21	
22	" 27	1:39	100	95	5	130	....	....	6	2.92	5.00	0.30	7,950	696	8.8	118	....	....	5 000	....	800		....	....	22	
23	" 27	6:57	100	95	5	130	....		6	2.71	4.45	0.25	6.675	688	10.3	117	....	....	5,000	....	650	....	....	....	23	
24	Jan. 1	16:54	135	35	74	175	....	....	6	2.34	19.30	0.27	28 950	673	2.3	123	....	....	1,500	....	8 000	....	....	....	24	
25	" 4	7:28	125	75	40	170	....	....	6	2.41	8.75	0.28	13 125	793	6.0	121	1.9	5.3	....	....	1,500	....	....	....	25	
26	" 4	16:30	125	75	40	170	....	....	6	2.79	6.28	0.45	9,425	75	0.8	117	2.8	3.4	2,100	....	1,700	....	....	....	26	Washed without Agitator.
27	" 4	23.14	125	75	40	170	....	....	6	2.46	3.43	0.27	5.125	681	13.3	117	3.4	5.1	2,100	....	2,000	....	....	....	27	
28	" 5	2:56	135	45	66	180	90	50	6	2.42	4.28	0.26	6,425	823	14.2	118	3.3	4.2	600	1,300	2,000	475	63	21	28	
29	" 5	8:29	140	45	68	180	90	50	6	2.47	4.98	0.30	7,475	925	12.4	118	3.2	4.1	600	1,200	1,000	550	54	8	29	
30	" 5	13:46	145	45	69	180	90	50	6	2.27	5.65	0.25	8,475	613	7.2	120	3.2	4.2	60	1,000	700	650	35	....	30	
31	" 5	19:35	145	45	69	180	90	50	6	2.42	5.25	0.27	7,875	707	8.9	119	3.1	4.3	600	950	550	100	90	83	31	

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began.		Suspended Matter.			Silica Turbidity.			Period of Coagulation.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
			Parts per Million.			Parts per Million.																				
	Date, 1900-1901.	Hour.	Subsided Water.	Coagulated Water.	Per Cent. Removed	Subsided Water.	Coagulated Water.	Per Cent. Removed.	Hours.		Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
32	Jan. 6	1:04	145	45	69	170	90	47	6	2.67	4.78	0.20	7,175	635	8.7	120	2.0	3.0	600	850	550	110	87	82	32	
33	" 6	6:02	150	50	67	170	90	47	6	2.38	5.06	0.15	7,575	570	7.3	121	3.0	4.0	600	850	......	90	89	85	33	
34	" 6	11:12	150	55	63	170	90	47	6	3.03	2.97	0.16	4,450	495	11.1	118	3.1	......	600	850	......	80	91	87	34	
35	" 6	15:20	150	60	60	170	90	47	6	2.83	3.94	0.20	5,875	709	12.1	119	2.6	4.4	600	850	......	70	92	88	35	
36	" 6	20:28	150	65	57	170	90	47	6	3.77	5.92	0.20	8,875	559	6.3	121	2.9	4.3	600	850	......	70	92	88	36	
37	" 7	2:35	150	70	53	170	90	47	6	3.22	5.67	0.22	8,525	679	8.0	120	2.9	3.9	......	......	......	......		......	37	
38	" 7	8:21	150	70	53	170	90	47	6	3.55	5.13	0.23	7,700	630	8.2	119	2.5	3.3	......	......	......	......	......	......	38	
39	" 7	13:43	150	70	53	170	90	47	6	3.63	5.03	0.15	7,550	516	6.8	121	3.2	4.1	......	......	......	......	......	......	39	
40	" 7	18:54	150	70	53	160	90	44	6	3.63	4.19	0.15	6,275	488	7.8	121	3.1	4.0	......	......	......	......	......	......	40	
41	" 7	23:14	150	70	53	160	90	44	6	3.94	5.60	0.15	8,400	550	6.5	122	3.1	4.0	......	......	......	......	......	......	41	
42	" 8	4:59	140	65	54	150	80	47	6	3.28	5.08	0.14	7,650	747	9.8	122	2.9	3.7	......	......	210	150	......	......	42	
43	" 8	10:12	130	65	50	150	80	47	6	2.99	4.42	0.17	6,625	534	8.1	120	3.2	4.1		......	210	230	......	......	43	
44	" 8	14:47	130	65	50	150	80	47	6	3.19	5.33	0.13	8,000	475	5.9	122	2.8	4.2	......	......	210	400	......	......	44	
45	" 8	20:27	130	65	50	150	80	47	6	3.72	5.30	0.16	7,950	517	6.5	122	3.0	4.0	......	......	210	230	......	......	45	
46	" 9	1:55	130	60	54	150	70	53	6	3.42	4.35	0.15	6,525	536	8.2	121	2.1	4.1	1,000	1,100	210	170	85	83	46	
47	" 9	7:25	120	60	50	150	70	53	6	3.55	4.87	0.16	7 300	525	7.2	121	3.0	4.1	1,000	1,300	300	250	81	75	47	
48	" 9	12:27	110	60	45	140	70	50	6	3.55	4.67	0.16	7,000	496	7.9	121	3.1	4.1	1,000	1,400	350	300	79	70	48	
49	" 9	17:17	110	60	45	140	70	50	6	3.95	5.13	0.13	7,700	469	7.0	122	3.0	4.6	1,000	1,500	390	600	60	40	49	
50	" 9	22:33	110	60	45	130	70	46	6	3.88	5.43	0.13	8,150	465	5.7	122	2.9	4.1	1,000	1,600	390	100	94	90	50	
51	" 10	4:40	110	60	45	130	70	46	6	3.60	4.95	0.13	7,425	378	5.2	122	3.1	4.0	1,300	1,800	400	600	66	54	51	
52	" 10	9:45	105	60	43	130	70	46	6	3.75	4.93	0.15	7,400	454	6.1	122	2.7	3.9	1,300	1,700	800	800	53	39	52	
53	" 10	14:50	105	60	43	130	70	46	6	3.72	6.75	0.12	10,125	411	4.1	123	2.9	4.3	1,300	1,700	900	700	59	46	53	
54	" 10	21:42	105	60	43	130	70	46	6	3.91	5.55	0.13	8 325	463	4.5	122	3.0	4.2	1,300	1,700	900	500	71	62	54	
55	" 11	3:23	105	80	24	130	80	38	6	3.39	4.80	0.12	7,200	424	5.9	122	3.0	4.0	850	1,700	800	300	82	65	55	
56	" 11	8:19	105	80	24	130	80	38	6	3.72	4.94	0.15	7,425	487	6.6	122	2.9	4.0	850	1,200	700	800	33	9	56	
57	" 11	13:24	105	80	24	130	80	38	6	3.72	6.85	0.13	10,275	450	4.4	123	2.4	3.8	850	800	700	75	91	91	57	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.12	0.13	7,675	435	5.7	122	3.1	4.1	850	500	700	80	84	90	58	

66	"	17	6:58	190	10	95	190	25	87	12	3.69	23.82	0.17	35,750	581	1.6	124	2.7	4.5	250	500	65	3	99	99	66
67	"	18	6:57	180	7	96	200	40	80	12	3.42	20.87	0.13	31,350	520	1.6	124	3.2	4.4	240	750	65	8	99	97	67
68	"	19	3:57	165	7	96	170	40	76	12	3.28	24.12	0.15	36,300	480	1.3	124	3.3	4.9	950	800	80	45	94	95	68
69	"	20	4:13	150	11	93	160	35	78	12	3.28	22.38	0.15	33,575	520	1.5	124	3.1	4.7	1,100	1,500	140	50	97	95	69
70	"	21	2:45	135	11	92	150	35	77	12	3.33	23.33	0.13	34,950	479	1.4	124	2.2	4.8	700	750	140	34	95	95	70
71	"	22	2:15	140	11	92	150	35	77	12	3.32	25.33	0.15	37,950	507	1.3	124	3.2	5.0	800	850	130	40	95	95	71
72	"	23	3:44	85	13	85	130	30	77	12	3.27	21.78	0.13	32,625	465	1.4	124	3.2	4.7	700	1,300	60	24	98	97	72
73	"	24	1:41	110	13	88	130	30	77	12	3.39	24.55	0.13	36,800	504	1.3	124	3.1	5.1	500	325	65	11	97	98	73
74	"	25	2:21	130	13	90	150	35	77	12	3.11	23.78	0.13	35,700	488	1.4	124	3.2	5.0	600	350	65	12	97	98	74
75	"	26	2:16	135	13	90	150	35	77	12	2.87	25.30	0.15	37,900	496	1.3	124	3.2	4.9	600	725	65	9	99	99	75
76	"	27	3:43	135	18	87	150	35	77	12	2.84	27.00	0.17	40,500	495	1.2	124	3.2	5.2	650	650	65	10	98	98	76
77	"	28	6:53	135	18	87	150	35	77	12	2.89	20.64	0.13	31,000	491	1.6	124	3.1	4.7	600	450	70	9	98	99	77
78	"	29	3:39	135	21	83	130	35	73	12	2.87	22.44	0.13	33,750	492	1.5	124	3.1	4.8	600	300	50	8	97	99	78
79	"	30	2:03	140	21	85	170	35	80	12	2.87	24.43	0.15	36,600	488	1.3	124	3.2	5.0	800	800	30	18	98	98	79
80	"	31	2:48	165	33	80	180	40	78	12	2.88	23.65	0.17	35,450	513	1.4	124	3.2	5.0	1,000	1,100	75	20	98	98	80
81	Feb.	1	2:37	195	35	82	190	45	76	12	2.85	23.63	0.17	35,425	517	1.5	124	3.1	5.0	1,100	1,500	120	60	96	95	81
82	"	2	2:25	200	21	90	200	35	83	12	3.06	28.75	0.13	43,100	492	1.1	124	3.2	4.8	1,100	850	140	28	97	98	82
83	"	3	7:18	200	25	88	210	40	81	12	2.97	22.12	0.12	33,175	552	1.7	124	3.1	4.9	1,800	2,200	90	28	99	98	83
84	"	4	5:34	200	22	89	210	35	83	12	2.98	23.63	0.15	35,425	495	1.4	124	3.2	4.4	4,200	3,000	200	150	95	96	84
85	"	5	5:21	195	22	89	200	35	83	12	2.89	23.98	0.17	35,950	536	1.5	124	2.6	4.6	3,800	3,300	200	180	95	95	85
86	"	6	5:21	200	45	78	210	40	81	12	2.97	23.08	0.15	34,600	514	1.5	124	2.7	4.6	4,500	3,400	200	130	98	97	86
87	"	7	4:35	215	12	94	190	40	79	12	2.81	21.82	0.15	32,750	505	1.5	124	2.6	4.5	5,100	3,500	130	60	98	99	87
88	"	8	2:33	165	12	93	170	40	76	12	2.81	24.68	0.15	37,000	499	1.4	124	2.6	4.5	5,800	3,600	150	110	97	98	88
89	"	9	3:23	125	25	80	170	50	71	12	2.91	19.88	0.15	29,800	536	1.8	124	2.5	4.4	2,300	4,300	250	70	98	97	89
90	"	9	23:16	140	25	82	180	50	72	12	2.85	9.12	0.13	13,675	533	3.9	123	2.6	3.7	2,300	3,100	275	40	99	98	90
91	"	10	8:33	150	40	73	190	80	58	12	2.73	13.98	0.15	20,900	536	2.5	123	2.6	4.2	2,500	1,900	100	33	98	99	91
92	"	10	22:31	170	40	76	190	80	58	12	2.72	15.20	0.13	22,750	536	2.3	124	2.6	4.3	2 600	1,900	90	70	96	97	92
93	"	11	22:02	170	45	73	190	85	55	12	2.99	16.33	0.13	24,450	577	2.3	124	2.6	5.2	2,200	1,800	100	50	97	98	93	Too much coagulant
94	"	12	14:40	165	28	83	180	55	70	6	2.97	10.62	0.15	15,950	544	3.4	123	2.9	4.7	4.500	3.400	450	32	99	99	94	[applied. Water over
95	"	13	3:02	165	50	70	170	75	54	6	2.97	8.18	0.17	12,275	541	4.4	122	2.7	4.7	3,400	1,700	500	8	99	99	95	[coagulated.
96	"	13	11:23	160	50	69	170	75	54	6	3.00	5.85	0.15	8,775	555	6.3	122	2.6	4.1	3,400	1,700	1,000	60	96	98	96	
97	"	13	17:22	160	50	69	170	75	54	6	2.97	7.76	0.15	11,650	480	4.1	122	2.6	4.5	3,400	1,700	1,000	2	99	99	97	
98	"	14	1:17	155	60	61	180	85	53	6	2.99	5.80	0.15	8,700	495	5.7	122	2.6	4.2	3,400	1,700	1,000	.....	.....	.....	98	
99	"	14	7:14	150	60	60	180	85	53	6	2.97	4.83	0.17	7,250	597	8.2	121	2.7	4.0	3,400	1,700	1,000	.....	.....	.....	99	
100	"	14	12:14	150	60	60	190	85	55	6	2.97	4.57	0.17	6,850	475	6.9	120	2.7	3.9	3,400	1,700	1,000	.....	.....	.....	100	
101	"	14	23:02	150	60	60	190	85	55	6	2.76	5.62	0.15	8,400	521	6.2	121	2.7	4.3	3,400	1,700	....	.....	.....	.....	101	
102	"	15	4:48	150	95	37	150	95	37	6	2.75	4.83	0.15	7,250	514	7.1	121	2.6	4.0	3,400	1,700	....	.....	.....	.....	102	
103	"	15	9:47	140	95	32	160	95	41	6	2.73	4.35	0.15	6,500	525	8.1	121	2.6	3.8	3,300	....	....	.....	.....	.....	103	
104	"	15	14:07	140	95	32	170	95	44	6	2.73	5.35	0.15	8,000	492	6.2	122	1.8	3.0	3,300	1,800	....	13	99	90	104	
105	"	15	19:47	140	95	32	180	95	47	6	2.75	7.01	0.15	10,500	480	4.6	122	2.6	4.2	3,300	1,800	....	.....	.....	.....	105	
106	"	16	2:57	140	95	32	170	95	44	6	2.73	4.35	0.13	6,500	516	8.0	122	2.7	3.9	3,300	1,800	....	8	99	100	106	
107	"	16	7:26	130	95	27	170	90	47	6	2.79	4.28	0.15	6,250	551	8.8	121	2.5	3.8	3,200	....	....	.....	.....	.....	107	
108	"	16	11:52	130	95	27	170	90	47	6	2.77	4.48	0.15	6,700	514	7.7	121	2.6	3.8	3,200	....	....	.....	.....	.....	108	
109	"	16	16:30	130	95	27	180	90	50	6	2.73	4.68	0.15	7,000	541	7.7	121	2.6	3.9	3,200	....	....	.....	.....	.....	109	
110	"	16	21:20	130	90	31	190	90	53	6	2.76	6.38	0.15	9,550	525	5.5	122	2.7	4.0	3,200	....	....	.....	.....	.....	110	
111	"	17	3:52	130	65	50	180	85	53	6	2.75	4.40	0.13	6,600	521	7.9	121	2.6	3.8	3,200	....	....	.....	.....		111	
112	"	17	8:24	140	60	57	180	80	56	6	2.76	3.85	0.15	5,750	510	8.8	120	2.6	3.5	3,100	....	....	.....	.....	.....	112	
113	"	17	12:24	150	60	60	180	80	56	6	2.78	3.78	0.13	5,650	525	9 3	120	2.6	3.6	3,100	....	....	.....	.....	.....	113	
114	"	17	16:19	150	60	60	170	80	53	6	2.78	5.23	0.15	7,800	503	6.4	122	2.6	3.7	3,100	....	....	.....	.....	.....	114	

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began. Date, 1900-1901.		Began. Hour	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water, Gallons. Filtered.	Quantities of Water, Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
115	Feb.	17	21:42	150	60	60	160	80	50	6	2.70	5.57	0.15	8,350	464	5.6	122	2.7	4.0	3,100	......	......	......	......	......	115	
116	"	18	3:25	140	60	57	140	80	43	6	2.73	4.65	0.13	6,950	492	7.1	122	2.6	3.8	3,100	2,800	......	......	......	......	116	
117	"	18	8:12	130	50	62	140	70	50	6	2.75	5.15	0.15	7,700	574	7.4	122	2.6	3.9	3,100	2,800	......	......	......	....	117	
118	"	18	16:03	110	40	64	140	60	57	6	2.33	4.05	0.15	6,050	474	8.2	120	2.5	3.8	3,100	2,800	......	......	......	......	118	
119	"	19	2:01	110	35	68	140	50	64	6	2.61	4.57	0.15	6,850	521	7.6	121	2.5	3.8	3 000	3,000	......	65	98	98	119	
120	"	19	6:44	120	35	71	150	50	67	6	2.74	4.13	0.13	6,200	574	9.3	121	2.5	3.9	3,000	3,000	......	8	100	100	120	
121	"	19	11:00	130	35	73	160	50	69	6	2.72	2.72	0.13	4,100	566	13.8	119	2.5	3.3	3,000	3,000	......	9	100	100	121	
122	"	19	23:02	130	35	73	170	50	71	12	2.46	15.63	0.17	23,400	596	2.5	123	2.6	4.3	3,000	3,000	......	19	99	99	122	
123	"	20	14:50	150	32	79	180	45	75	12	2.55	17.98	0.18	26,950	571	2.1	123	2.7	4.1	2.800	3,200	300	21	99	99	123	
124	"	21	9:00	155	30	81	170	40	76	12	2.61	19.18	0.17	28,750	536	1.9	124	2.8	4.3	2.000	2.000	750	19	99	99	124	
125	"	22	4:21	145	29	80	170	27	84	12	2.64	22.13	0.15	33,200	541	1.6	124	2.7	4.6	1,200	2,700	300	31	99	97	125	
126	"	23	2:38	150	23	85	180	40	78	12	2.52	20.52	0.15	30,800	545	1.8	124	2.7	4.5	1,200	3,000	300	13	99	99	126	
127	"	23	23:18	165	23	86	180	40	78	12	2.70	19.90	0.17	29,850	492	1.7	124	2.7	4.4	1,200	3,300	300	4	100	100	127	
128	"	24	19:22	185	25	86	190	45	76	12	2.79	16.50	0.17	24,700	621	2.5	124	2.7	4.0	2 200	3,600	300	220	94	90	128	
129	"	28	4:44	155	22	86	170	17	90	12	2.45	28.18	0.15	42,300	563	1.3	125	4.0	8.3	1,700	1,900	325	115	94	93	129	New Sand.
130	Mar.	1	9:04	140	17	88	160	21	87	12	2.36	23.37	0.20	35,000	751	2.1	124	3.9	10.4	1,400	1.700	200	80	95	94	130	
131	"	2	8:34	130	22	83	140	27	81	12	2.48	24.96	0.18	37,400	671	1.8	124	3.7	10.2	2,000	1,400	170	85	94	96	131	
132	"	3	9:48	120	10	92	140	30	79	12	2.43	22.52	0.18	33,800	668	2.0	124	3.7	10.5	2,400	2,500	250	100	96	96	132	
133	"	4	8:30	120	8	93	150	27	82	12	2.33	22.30	0.20	33 400	713	2.1	124	3.5	10.5	1,600	1,800	300	45	98	97	133	
134	"	5	7:00	130	19	85	170	28	84	12	2.31	20.68	0.15	31.000	561	1.8	124	3.5	9.4	1,200	850	160	60	93	95	134	
135	"	6	3:50	140	24	83	170	35	79	12	2.30	21.60	0.15	32,400	593	1.8	124	3.9	7.9	1,000	950	120	29	97	97	135	
136	"	7	1:35	150	18	88	150	27	82	12	2.42	25.12	0.16	37,700	568	1.5	124	4.0	8.2	750	750	100	26	97	97	136	
137	"	8	2:52	140	17	88	130	40	69	12	2.45	24.85	0.18	37 300	522	1.4	124	3.8	9.6	800	800	150	28	97	97	137	
138	"	9	3:54	130	16	88	140	45	68	12	2.42	19.38	0.18	29,000	601	2.1	124	3.7	10.0	950	650	90	17	97	98	138	Run broken by low
139	"	9	23:28	125	15	88	140	50	64	12	2.43	12.62	0.18	18 900	668	3.5	123	3.8	10.0	950	650	90	28	96	97	139	[level of water in
140	"	10	12:16	115	15	86	140	55	61	12	2.42	18.06	0.18	27,100	656	2.4	124	3.5	8.4	600	950	160	35	96	94	140	[basins.
141	"	11	6:31	110	20	82	140	55	61	12	2.43	19.88	0.18	29,800	626	2.1	124	3.6	8.9	600	600	140	21	92	97	141	
142	"	12	2:35	105	28	73	130	65	50	12	2.24	19 93	0.18	29,900	555	1.9	124	3.6	8.4	700	950	120	40	96	94	142	
143	"	12	22:42	105	28	73	130	65	50	12	2.07	14.60	0.18	21,9 0	624	2.8	123	3.5	7.2	700	950	95	31	97	95	143	
144	"	13	13:29	100	50	50	120	60	50	12	2.14	13.98	0.18	21,000	582	2.8	123	3.5	7.7	800	850	120	50	94	94	144	
145	"	14	3:39	80	65	19	100	75	25	6	2.11	9.78	0.18	14,700	657	4.5	122	3.8	6.8	750	400	300	45	89	94	145	

146	Mar.	14	18:37	70	65	7	100	75	25	6	1.18	10.88	0.18	16,800	558	3.4	123	3.5	7.4	750	400	580	45	89	94	146
147	"	15	00:41	75	65	13	100	75	25	6	1.78	8.45	0.18	12,700	589	4.5	123	3.6	6.6	750	400	400	35	91	95	147
148	"	15	9:18	85	70	18	110	80	27	6	1.80	7.77	0.16	11,700	593	5.0	123	3.6	6.2	600	800	250	21	97	97	148
149	"	15	17:14	85	80	6	110	80	27	6	1.80	8.43	0.18	12,700	517	4.1	122	3.7	6.8	600	800	240	65	92	89	149
150	"	16	1:51	95	70	26	110	75	34	6	1.89	7.25	0.16	10,900	585	5.4	122	3.6	6.0	500	750	275	65	91	87	150
151	"	16	9:16	100	85	15	110	75	32	6	1.89	8.33	0.16	12,500	536	4.3	122	3.7	6.3	500	750	300	65	91	87	151
152	"	16	17:46	100	85	15	110	75	32	6	1.89	8.37	0.18	12,600	532	4.2	122	3.7	6.3	500	750	300	65	91	87	152
153	"	17	2:19	95	40	58	100	75	25	6	1.79	8.03	0.15	12,100	518	4.3	123	3.6	6.3	750	1,000	300	31	97	96	153
154	"	17	10:30	90	40	56	100	75	25	6	1.80	9.10	0.16	13,700	491	3.6	123	3.7	6.3	750	1,000	300	34	97	96	154
155	"	17	19:46	85	40	41	100	75	25	6	1.80	8.66	0.15	13,000	525	4.0	123	3.5	6.4	750	1,000	300	60	94	92	155
156	"	18	4:36	80	35	56	95	70	26	6	1.80	7.68	0.15	11,500	518	4.5	122	3.5	6.2	1,100	500	300	32	94	97	156
157	"	18	12:26	75	35	53	95	70	26	6	1.80	10.75	0.16	16,100	547	3.4	123	3.5	6.5	1,100	500	275	25	95	98	157
158	"	18	23:21	70	35	50	95	70	26	6	1.72	8.90	0.16	13,350	541	4.1	122	3.5	6.4	1,100	500	275	30	94	97	158
159	"	19	8:25	80	60	25	100	65	35	6	1.72	10.95	0.12	16,400	338	2.1	123	3.5	6.8	800	500	250	14	97	98	159
160	"	19	19:24	90	60	33	100	65	35	6	1.72	8.40	0.16	12,600	585	4.6	122	3.3	6.3	800	500	220	150	70	81	160
161	"	20	4:03	100	65	35	120	70	42	6	1.71	8.43	0.28	12,650	923	7.3	121	3.3	6.2	900	600	210	50	92	94	161
162	"	20	12:43	110	65	41	120	70	42	6	1.72	9.78	0.16	14,700	488	3.3	123	3.5	6.7	900	600	200	50	92	94	162
163	"	20	22:40	115	65	44	120	70	42	6	1.72	8.57	0.16	12,900	547	4.2	123	3.5	6.3	900	600	200	95	84	89	163
164	"	21	7:24	120	60	50	130	75	42	6	1.72	6.77	0.15	10,100	560	5.5	122	3.5	5.6	1,600	1,100	1,000	75	93	95	164
165	"	21	14:19	125	60	52	130	75	42	6	2.00	8.45	0.18	12,700	525	4.1	122	3.6	5.9	1,600	1,100	1,000	70	94	96	165
166	"	21	22:51	125	60	52	130	75	42	6	2.16	6.48	0.16	9,700	552	5.7	122	3.5	5.7	1,600	1,100	1,100	140	87	91	166
167	"	22	5:36	130	65	50	160	85	47	6	2.16	5.53	0.15	8,300	530	6.4	121	3.6	5.3	800	1,700	1,300	26	98	97	167
168	"	22	11:17	135	65	52	160	85	47	6	2.16	7.27	0.16	10,900	503	4.6	122	3.5	5.4	800	1,700	1,300	70	96	91	168
169	"	22	18:43	135	65	52	160	85	47	6	2.33	6.10	0.16	9,100	551	6.0	122	3.5	5.5	800	1,700	....	200	88	75	169
170	"	23	00:55	135	65	52	160	85	47	6	2.33	5.82	0.15	8,700	589	6.8	122	3.4	5.6	800	1,700	....	95	94	88	170
171	"	23	6:53	140	100	29	230	130	43	6	2.82	4.40	0.15	6,600	540	8.2	121	3.5	6.1	....	....	....	65	......	......	171
172	"	23	11:36	150	100	33	230	130	43	6	3.32	3.98	0.16	6,000	548	9.1	120	3.5	4.7	....	....	....	90	......	.....	172
173	"	23	15:45	170	100	41	230	130	43	6	2.53	4.68	0.15	7,000	563	8.0	121	3.5	5.0	....	....	....	......	......	.....	163
174	"	23	20:35	180	100	44	230	130	43	6	2.67	4.22	0.15	6,300	494	7.8	121	3.5	4.9	....	....	....	.....		......	174
175	"	24	10:02	200	14	93	270	50	81	12	2.98	21.08	0.16	31,600	555	1.7	124	3.4	6.5	3,000	....	....	160	......	95	175
176	"	25	7:17	250	80	68	230	120	48	12	3.15	22.22	0.18	33,300	644	1.9	124	3.5	6.6	6,500	1,900	350	55	97	99	176
177	"	26	5:41	300	28	91	440	50	89	12	3.91	24.82	0.16	37,300	582	1.6	124	3.4	7.0	6,500	3,100	300	40	99	99	177
178	"	27	6:40	500	55	89	550	75	86	12	4.76	23.98	0.15	36,000	561	1.5	124	3.6	6.6	6,000	4,900	275	40	99	99	178
179	"	28	6:48	700	35	95	650	50	92	12	3.50	23.77	0.16	35,600	598	1.7	124	3.5	7.4	3,800	4,000	375	17	100	100	179
180	"	29	6:44	700	50	93	700	80	89	12	4.43	18.55	0.16	27,800	608	2.2	124	3.5	7.3	1,500	2,100	500	50	98	97	180
181	"	30	1:27	600	55	91	575	100	83	12	4.59	6.98	0.16	10,500	494	4.7	122	3.5	5.0	2,900	1,900	425	55	97	98	181
182	"	30	9:01	575	55	90	575	100	83	12	1.46 4.14	10.35	0.13	15,500	507	3.3	123	3.5	8.1	2,900	1,900	425	21	99	99	182
183	"	30	19:30	575	55	90	575	100	83	12	1.49 4.09	9.27	0.15	13,900	526	3.8	123	3.5	7.3	2,900	1,900	425	23	99	99	183
184	"	31	4:55	550	60	89	850	90	89	12	1.47 3.96	10.16	0.15	15,200	532	3.5	123	3.4	7.6	....	4,900	350	25	99	.....	184
185	"	31	15:14	550	60	89	850	90	89	12	1.48 4.14	10.13	0.15	15,200	546	3.6	123	3.5	8.1	4,000	4,900	300	12	100	100	185
186	Apr.	1	1:31	525	95	82	625	140	78	12	1.50 4.61	6.92	0.13	10,400	525	5.0	123	3.5	6.5	5,000	3,500	400	13	100	100	186
187	"	1	8:34	500	95	81	625	140	78	12	1.49 4.66	6.95	0.16	10,450	567	5.5	122	3.5	6.5	5,000	3,500	475	50	99	99	187
188	"	1	15:41	500	95	81	625	140	78	12	1.88 4.67	5.92	0.16	8,900	522	5.9	121	3.5	6.3	5,000	3,500	475	22	99	100	188
189	"	1	21:46	500	95	81	625	140	78	12	1.98 4.01	4.98	0.16	7,450	575	7.7	121	3.4	6.3	5,000	3,500	475	20	99	100	189

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
190	Apr. 2	2:55	475	95	80	575	140	76	12	1.98 / 3.89	3.28	0.16	4,900	510	10.4	119	3.4	5.6	4,800	3,700	400	25	99	99	190	
191	" 2	22:35	450	95	79	575	140	76	12	1.98 / 4.32	10.12	0.13	15,200	517	3.4	123	3.3	10.4	4,800	3,700	350	20	99	100	191	
192	" 3	8:50	425	80	81	575	100	83	12	1.99 / 4.32	8.62	0.13	12,900	555	4.3	123	3.5	9.3	4,000	4,200	375	14	100	100	192	
193	" 3	17:35	400	80	80	575	100	83	12	1.97 / 4.33	8.15	0.16	12,200	585	4.8	122	3.5	8.7	4,000	4,200	375	23	99	99	193	
194	" 4	1:54	400	75	81	500	95	81	12	1.99 / 3.90	7.50	0.15	11,250	534	4.7	123	3.6	8.6	4,500	3,400	400	14	100	100	194	
195	" 4	9:33	400	75	81	500	95	81	12	1.99 / 3.49	7.32	0.15	11,000	564	5.1	123	3.5	8.4	4,500	3,400	400	17	100	100	195	
196	" 4	17:01	400	75	81	500	95	81	12	1.97 / 3.11	9.18	0.16	13,800	551	4.0	123	3.5	10.5	4,500	3,400	400	7	100	100	196	
197	" 5	1:22	375	45	88	500	60	88	12	1.99 / 2.99	8.32	0.13	12,500	513	4.1	123	3.5	10.8	3,900	2,600	200	7	100	100	197	
198	" 5	9:49	375	45	88	500	60	88	12	1.99 / 4.43	8.83	0.15	13,200	495	3.7	123	3.5	10.7	3,900	2,600	100	4	100	100	198	
199	" 5	18:48	375	45	88	500	60	88	12	1.99 / 4.44	8.06	0.20	12,100	822	6.8	122	3.5	10.8	3,900	2,600	90	8	100	100	199	
200	" 8	10:18	350	40	89	425	55	87	12	1.01 / 4.27	12.18	0.15	18,250	578	3.2	123	4.4	10.7	4,300	2,700	170	110	96	97	200	New Sand.
201	" 8	22:38	350	40	89	430	55	87	12	1.01 / 4.06	8.52	0.15	12,800	547	4.3	123	4.4	10.6	4,300	2,700	170	40	98	99	201	
202	" 9	7:18	400	55	86	475	75	84	12	1.02 / 4.26	8.18	0.15	12,300	491	4.0	123	4.3	10.5	5,000	2,300	400	50	98	99	202	
203	" 9	15:38	410	55	89	475	75	84	12	1.01 / 4.45	8.85	0.16	13,300	541	4.1	123	4.5	10.8	5,000	2,300	475	60	97	99	203	
204	" 10	00:39	400	55	86	475	75	84	12	1.00 / 4.43	7.05	0.15	10,550	583	5.0	122	4.4	10.8	5,000	2,300	475	27	99	99	204	
205	" 10	7:51	390	60	85	475	80	83	12	1.00 / 4.43	9.06	0.15	13,600	508	3.7	123	4.5	10.6	4,700	3,700	450	32	99	99	205	

206	Apr.	10	17:03	390	55	86	475	80	83	12	0.72 4.45	9.30	0.16	13,950	525	3.8	123	4.4	10.8	4,700	3,700	450	55	99	99	206	
207	"	11	2:31	380	50	87	500	75	85	12	0.74 4.41	8.82	0.15	13,250	498	3.8	123	4.5	10.6	3,600	3,000	800	35	99	99	207	
208	"	11	11:29	370	50	86	500	75	85	12	0.73 4.43	11.27	0.15	16,900	548	3.3	123	4.4	10.8	3,600	3,000	290	50	98	99	203	
209	"	11	22:54	370	50	86	500	75	85	12	0.72 4.41	8.92	0.15	13,400	528	4.0	123	4.6	10.8	3,600	3,000	275	20	99	99	209	
210	"	12	7:58	380	70	81	425	95	78	12	0.73 4.43	10.13	0.16	15,200	525	3.5	123	4.4	10.7	2,800	2,200	475	35	98	99	210	
211	"	12	18:16	355	50	86	425	95	78	12	0.73 4.45	9.15	0.16	13,700	558	4.1	123	4.5	10.7	2,300	2,200	475	90	96	96	211	
212	"	13	3:35	350	33	91	425	60	86	12	0.72 4.43	11.00	0.15	16 500	512	3.1	123	4.6	10.7	4,400	2,400	300	82	99	99	212	
213	"	13	14:44	340	45	87	425	60	86	11	0.72 4.43	12.42	0.16	18,600	574	3.1	123	4.4	10.7	4,400	2,400	200	18	99	100	213	
214	"	14	3 19	330	45	86	425	60	86	12	0.73 4.41	12.62	0.13	18,900	495	2.6	124	4.4	10.6	3,900	2,400	200	18	99	100	214	
215	"	14	16:04	320	45	86	425	60	86	12	0.73 4.44	11.15	0.16	16,700	559	3.3	123	4.5	10.7	3,900	2,400	200	18	99	100	215	
216	"	15	3:23	310	45	85	425	60	86	12	0.73 4.43	11.40	0.15	17,100	517	3.0	123	4.6	10.6	3,500	2,600	225	18	99	99	216	
217	"	15	14:56	300	45	85	425	60	86	12	0.73 4.44	12.37	0.16	18,500	550	3.0	123	4.4	10.7	3,500	2,600	250	25	99	99	217	
218	"	16	3:28	310	45	85	425	60	86	12	0.73 4.43	13.16	0.15	19,700	544	2.8	124	4.5	10.5	3,400	1,700	225	13	99	100	218	
219	"	16	16:49	320	45	86	425	60	86	12	0.73 4.44	12.28	0.15	19,400	506	2.9	124	4.3	10.7	3,400	1,700	210	16	99	100	219	
220	"	17	5:55	330	40	88	500	65	87	12	0.72 4.42	13.25	0.16	19,850	494	2.5	123	4.5	10.7	3,000	1,500	150	8	99	100	220	
221	"	17	19:20	335	40	88	500	65	87	12	0.73 4.44	7.25	0.16	11,050	623	5.6	122	4.4	10.7	3,000	1,500	160	12	99	100	221	
222	"	19	2:51	335	33	90	425	50	88	12	0.73 4.44	12.58	0.15	18,800	555	2.9	123	4.6	10.7	2,500	1,800	110	16	99	99	222	
223	"	19	15:35	340	33	90	425	50	88	12	0.73 4.42	17.85	0.15	26,750	547	2.0	124	4.4	10.7	2 500	1,800	110	10	99	100	223	
224	"	20	9:35	350	50	86	400	70	83	12	0.72 4.43	16.85	0.16	25,250	571	2.3	124	4.5	10.7	3,900	2,200	250	19	99	99	224	
225	"	21	2:36	340	45	87	400	65	84	12	0.73 4.42	20.53	0.16	30,500	547	1.8	124	4.4	10.7	3,100	4,100	170	21	99	99	225	
226	"	21	23:18	340	45	87	400	65	84	12	0.73 4.42	19.97	0.16	29,950	524	1.8	124	4.4	10.7	3,100	4,100	170	15	100	100	226	
227	"	22	19:26	340	50	85	375	70	81	12	0.73 4.42	15.93	0.13	23,850	503	2.1	124	4.4	10.6	2,200	2,000	210	9	100	100	227	
228	May	3	8:45	460	35	92	450	70	84	6	5.08	23.88	0.16	35,800	590	1.6	124	2.7	7.6	2,800	4,100	500	375	91	90	228	First run on equation
229	"	4	8:48	460	50	89	510	75	85	6	4.67	23.52	0.16	35,300	526	1.5	124	2.7	7.4	3,400	2,700	600	190	93	95	229	of filters. Using
230	"	5	7:27	460	50	89	510	70	86	6	4.11	23.50	0.15	35,300	508	1.4	124	2.6	7.1	2,100	1,600	400	130	92	94	230	water from No. 3
231	"	6	6:06	420	30	93	510	65	87	6	4.14	22.23	0.16	33,500	537	1.6	124	2.6	6.7	1,600	1,600	400	135	92	92	231	Basin.
232	"	7	4:30	375	35	91	480	80	83	6	4.61	26.08	0.16	39,200	545	1.4	124	2.7	6.8	1,500	1,900	275	85	96	94	232	
233	"	8	6:45	370	35	91	430	50	88	6	5.18	26.50	0.16	38,300	510	1.3	124	2.7	6.5	2,600	2,000	220	50	98	98	233	
234	"	9	8:25	365	75	79	420	95	77	6	4.54	9.95	0.13	14,950	594	4.0	123	2.8	4.7	2,100	2,000	300	55	97	97	234	
235	"	9	18:30	365	75	79	420	95	77	6	3.12	12.18	0.16	18,250	518	2.8	123	2.7	5.7	2,100	1,800	390	180	86	91	235	

NOTE.—Where bacterial efficiency is given as 100 per cent the efficiency is over 99.5 per cent.

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
236	Apr. 10	6:51	365	70	81	430	140	67	6	3,05	1,68	0,16	2,550	385	1,5	114	2,8	3,1	3,200	1,300	425	180	86	94	236	
237	" 10	14:00	365	70	81	430	140	67	3	4,07	6,35	0,13	9,800	494	5,0	122	2,7	5,0	1,300	1,300	450	90	93	93	237	
238	" 10	20:40	365	70	81	430	140	67	3	4,14	6,20	0,13	9,300	529	5,7	122	2,6	4,2	1,800	1,900	450	90	95	95	238	
239	" 11	3:00	360	60	83	420	120	71	3	4,05	6,83	0,16	10,250	580	5,6	122	2,7	4,3	2,000	1,900	500	70	96	97	239	
240	" 11	16:00	360	60	83	420	120	71	6	0,49 4,07	15,30	0,13	22,900	503	2,2	124	2,7	8,0	4,000	1,300	600	70	95	98	240	
241	" 12	7:27	340	25	93	400	55	86	6	0,48 4,05	19,65	0,13	29,500	518	1,8	124	2,7	8,9	4,500	1,300	400	165	87	96	241	
242	" 13	3:15	330	27	92	390	60	85	6	0,21 4,07	17,65	0,13	26 500	435	1,6	124	2,7	8,5	2,300	1,300	300	55	96	98	242	
243	" 13	21:03	320	27	92	390	60	85	6	0,24 4,05	18,27	0,15	27,400	525	1,9	124	2,7	8,4	1,200	1,400	325	130	91	89	243	
244	" 14	15:28	285	26	91	350	55	84	12	0,47 4,07	21,90	0,15	32,800	513	1,6	124	2,7	10,4	1,700	1,400	425	85	94	95	244	
245	" 16	11:14	245	26	89	300	50	83	12	0,48 4,07	21,45	0,16	32,100	488	1,5	124	2,7	10,4	2,500	1,400	170	80	94	97	245	Finished equation [test.
246	" 18	21:00	235	75	68	270	90	67	24	0,49 2,43	17,22	0,16	25,800	526	2,0	124	2,7	10,7	2,200	1,400	700	150	89	93	246	
247	" 19	14:23	225	50	78	290	80	72	24	0,48 2,44	17,08	0,16	25,600	576	2,2	124	2,7	10,7	1,200	1,200	550	70	94	94	247	
248	" 24	6:02	200	50	75	190	75	61	24	0,49 2,30	15,71	0,13	23,500	494	2,1	124	2,6	10,8	1,300	1,200	1,200	120	90	91	248	
249	" 24	21:53	175	40	77	190	60	68	24	0,49 2,06	20,42	0,13	30,600	499	1,6	124	2,7	10,7	1,300	1,200	1,200	375	69	71	249	
250	" 25	18:26	155	40	74	180	65	64	24	0,49 2,04	18,07	0,16	27,100	521	1,9	124	2,6	10,8	1,300	1,200	1,600	100	92	92	250	
251	May 26	12:40	155	27	83	180	45	75	24	0,48 2,06	21,68	0,16	32,500	520	1,6	124	2,7	10,7	2,200	2 300	550	46	98	98	251	
252	" 27	10.37	150	26	83	170	45	73	24	0,49 2,00	17,85	0,13	26,750	537	2,0	124	2,7	10,8	2,500	2,000	450	100	95	96	252	

253	May	26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	253	
254	"	28	21:58	170	60	65	190	90	53	24	0.25 1.92	19.86	0.15	29 800	536	1.8	124	2.7	10.8	1,800	550	400	50	91	97	254	
255	"	29	17:59	175	85	51	210	90	57	24	0.25 1.89	20.20	0.16	30,300	536	1.8	124	2.7	10.8	1,500	1 100	375	130	88	91	255	
256	"	30	14:21	200	55	73	200	70	65	24	0.48 1.86	16.03	0.16	24,000	570	2.4	124	2.7	10.8	1,200	1,300	500	275	79	77	256	
257	"	31	6:33	200	55	73	220	70	68	24	0.49 1.99	18.07	0.13	27,100	510	1.9	124	2.6	10.8	1,500	550	200	45	92	97	257	
258	June	1	00:45	200	55	73	230	63	72	24	0.49 2.00	14.38	0.16	21,500	555	2.6	124	2.7	7.8	1,000	550	700	......	....	......	258	
259	"	1	15:18	210	55	74	300	60	80	24	0.49 2.00	16.03	0.13	24,000	514	2.1	124	2.7	10.8	1,200	750	220	85	89	93	259	
260	"	2	7:28	220	55	75	300	60	80	24	0.68 2.07	16.98	0.16	25,400	537	2.1	124	2.6	10.8	1,400	750	300	200	73	86	260	
261	"	3	00:37	245	55	76	325	60	82	24	0.70 2.42	19.67	0.16	29,300	516	1.8	124	2.6	10.8	3,600	750	230	200	73	94	261	
262	"	3	20:27	245	30	88	325	45	86	24	1.49 2.70	28.28	0.16	42,400	525	1.2	124	2.6	10.8	3,000	700	350	150	79	95	262	
263	"	5	00:53	245	15	94	300	18	94	24	1.50 2.99	25.70	0.16	38,600	420	1.1	124	2.6	10.8	2,500	2,900	500	425	85	83	263	Coagulant tank overflowed, causing filter to clog.
264	"	6	3:32	255	18	93	300	20	93	24	1.99 2.66	26.03	0.16	39,000	540	1.4	124	2.7	10.8	3,400	2,100	700	170	92	95	264	
265	"	7	5:43	260	15	94	300	25	92	24	1.99 2.79	45.85	0.16	68,500	532	0.8	125	2.6	10.8	2,900	1,000	500	275	73	91	265	
266	"	9	3:44	200	18	91	270	20	93	24	1.98 2.48	42.95	0.16	64,300	578	0.9	125	2.6	10.8	2,700	1,300	230	140	89	95	266	
267	"	10	22:51	200	33	83	290	35	88	24	1.88 1.73	31.39	0.16	47,100	561	1.2	124	2.6	10.8	2,800	1,400	250	300	79	89	267	
268	"	12	5:24	220	45	80	325	60	82	24	2.06 1.25	30.43	0.15	45,700	540	1.2	124	2.5	10.9	2 700	1,500	240	...	......	......	268	Beginning with run No. 268 on even runs, filter washed — agitator.
269	"	13	11:59	230	30	87	325	50	85	24	2.36 1.27	26.70	0.13	40,100	499	1.2	124	2.8	10.8	2,300	1,200	475	150	88	93	269	+ "
270	"	14	14:49	220	20	91	325	50	85	24	0.98 1.27	30.88	0.13	45,500	555	1.2	124	2.7	10.1	1,100	1,200	300	120	90	89	270	— "
271	"	15	21:20	205	23	89	350	40	89	24	0.97 1.35	31.90	0.16	47,800	547	1.1	124	2.6	10.8	1,000	1,500	210	75	95	93	271	+ "
272	"	17	5:23	235	70	70	325	85	74	24	0.97 1.38	24.20	0.15	36,300	671	1.8	124	2.6	10.8	950	950	240	190	80	80	272	— "
273	"	18	5:44	250	35	86	290	40	86	24	0.98 1.95	43.48	0.16	65,100	617	0.9	125	2.6	10.8	1,000	850	325	100	88	90	273	+ "
274	"	20	1:23	225	17	92	270	28	90	24	0.95 1.28	49.08	0.13	72,300	520	0.7	125	2.6	10.8	725	2,800	140	65	98	91	274	— "
275	"	22	2:30	210	10	95	290	20	93	24	0.97 2.25	45.62	0.15	68,500	574	0.8	125	2.6	10.8	1,200	1,000	130	85	92	93	275	+ "
276	"	24	8:02	175	100	43	300	130	57	0.50	2.77	9.23	0.15	13,80	618	4.5	123	2.7	10.7	....	....	....	......	......	......	276	— "
277	"	24	17:25	150	115	23	200	150	25	0.50	3.14	8.95	0.16	13,400	593	4.4	123	2.6	10.8	2.000	....	750	190	....	91	277	+ "
278	"	25	2:32	125	90	28	150	110	27	0.50	6.20	12.00	0.15	18,000	488	2.7	123	2.7	10.7	2,400	1,400	475	475	66	80	278	— "
279	"	25	19 20	125	70	44	250	90	64	0.50	6.20	12.67	0.15	18,800	371	2.0	123	2.5	10.5	2,100	1,400	475	80	94	96	279	+ "

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began.		Suspended Matter. Parts per Million.		Suspended Matter.	Silica Turbidity. Parts per Million.		Silica Turbidity.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
	Date, 1900-1901.	Hour.	Subsided Water.	Coagulated Water.	Per Cent. Removed.	Subsided Water.	Coagulated Water.	Per Cent. Removed.			Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
280	June 27	12:00	165	40	76	300	50	83	24	0.19 2.73	12.78	0.13	19,200	531	2.8	123	3.5	10.9	2,100	1,900	900	600	68	71	280	+ Agitater. New Sand.
281	" 28	00:55	175	15	91	300	20	93	24	0.19 2.74	15.62	0.12	23,500	396	1.7	124	3.4	10.8	2,100	600	400	350	42	83	281	— "
282	" 28	16:39	175	11	94	290	15	95	24	0.39 2.64	8.62	0.16	12,950	353	2.7	122	3.9	10.8	2.000	2,000	240	550	72	72	282	+ "
283	" 29	1:26	175	16	91	290	21	93	24	0.39 2.63	11.43	0.13	17,150	435	2.5	123	3.4	10.9	1,500	1,700	250	65	96	96	283	— "
284	" 29	13:17	170	17	90	290	23	92	24	0.58 2.52	8.35	0.12	12,500	341	2.7	122	3.4	10.9	1.300	1,400	275	160	89	88	284	— "
285	" 29	21:45	170	17	90	325	22	93	24	0.56 2.43	7.02	0.15	10,500	290	2.8	122	3.4	10.9	1,400	1,300	250	90	93	94	285	+ "
286	" 30	4:55	190	17	91	290	22	92	24	0.57 2.52	7.82	0.13	11,700	502	4.5	123	4.0	10.8	1,600	1,200	300	95	92	94	286	— "
287	" 30	12:52	200	19	90	350	25	93	24	0.79 2.60	6.10	0.13	9,150	300	3.3	122	3.9	10.8	1,300	1,200	240	89	97	97	287	+ "
288	" 30	19:06	205	16	92	350	25	93	24	0.78 2.43	6.47	0.10	9,525	384	4.0	122	3.7	10.7	1,300	1,100	250	250	77	81	288	— "
289	July 1	1:40	250	15	94	350	25	93	24	0.79 2.56	11.33	0.10	17,000	361	2.1	123	3.6	10.8	1,400	950	275	50	95	96	289	+ "
290	" 1	13:06	300	15	95	350	27	92	24	0.79 2.72	8.00	0.12	12,000	337	2.7	122	3.6	10.8	1,100	650	140	28	96	97	290	— "
291	" 1	21·12	320	15	95	375	27	93	24	0.19 2.74	9.95	0.13	14,900	336	2.3	123	3.7	10.7	1,200	1,200	240	130	89	92	291	+ "
292	" 2	7 17	330	15	95	400	26	94	24	0.19 2.88	14.80	0.10	22,200	363	1.6	124	3.6	10.7	2,600	1,500	800	650	57	75	292	— "
293	" 2	22:11	340	15	96	400	25	94	24	0.40 3.04	11.25	0.13	16,900	401	2.4	124	3.7	10.7	1,500	1,000	275	70	93	95	293	+ "
294	" 3	9:34	330	15	95	375	27	93	24	0.39 2.97	10.83	0.10	15,500	337	2.2	124	3.6	10.7	1.500	1,200	600	28	98	98	294	— "
295	" 3	20.00	320	15	95	375	30	92	24	0.59 3.08	9.20	0.13	18,800	289	2.1	123	3.6	10.8	1,600	1,300	90	24	98	99	295	+ "

296	July	4	5:18	320	15	95	375	30	92	24	0.58 3.05	9.98	0.18	15,000	346	2.8	128	3.8	10.8	1,800	1,000	150	35	97	98	296	—	Agitator.
297	"	4	15:23	320	15	95	375	30	92	24	0.79 2.96	8.38	0.10	12,550	324	2.6	128	3.7	10.8	1,600	1,500	250	55	96	97	297	+	"
298	"	4	23:52	320	15	95	375	30	92	24	0.79 2.92	11.00	0.10	16,500	348	2.1	124	3.8	10.8	1,400	1,500	325	47	97	97	298	—	"
299	"	5	10:58	310	15	95	350	28	92	24	0.19 2.98	17.22	0.10	25,900	323	1.3	124	3.7	10.8	1,800	1,600	130	36	98	98	299	+	"
300	"	6	4:17	300	15	95	375	30	92	24	0.20 2.90	18.77	0.12	28,100	361	1.3	124	3.7	10.8	1,600	1,300	170	28	98	98	300	—	"
301	"	6	23:10	310	15	95	400	33	92	24	0.19 2.82	17.72	0.13	26,800	331	1.2	124	3.8	10.8	1,900	1,200	190	42	96	98	301	+	"
302	"	7	17:01	320	19	94	400	34	92	24	0.19 2.90	17.33	0.13	26,000	416	1.6	124	3.7	10.7	1,600	900	100	18	98	99	302	—	"
303	"	9	13:50	315	23	93	375	40	89	24	0.48 3.15	16.33	0.10	24,500	364	1.5	124	3.6	10.9	2,000	1,100	225	200	82	90	303	+	"
304	"	10	6:10	310	21	93	350	35	90	24	0.46 3.13	17.42	0.10	26,200	369	1.4	124	3.3	10.9	1,900	6,000	1,900	300	95	84	304	—	"
305	"	10	23:41	285	21	93	325	35	89	24	0.48 2.90	22.03	0.12	33,100	353	1.1	124	3.1	10.9	1,700	2,100	2,000	400	81	77	305	+	"
306	"	11	21.50	270	20	93	375	35	91	24	0.48 2.36	26.92	0.10	40,300	367	0.9	124	3.1	10.9	1,600	1,900	2,000	500	58	69	306	—	"
307	"	13	00:51	255	17	93	375	45	89	24	0.46 2.78	20.15	0.12	30,200	337	1.1	124	3.4	10.7	1,600	1,300	550	250	81	84	307	+	"
308	"	13	22:32	295	18	94	280	40	86	24	0.48 3.06	20.25	0.10	30,400	315	1.0	124	3.7	10.7	1,500	700	180	80	89	95	308	—	"
309	"	14	18:58	250	19	92	280	40	86	24	0.47 2.88	15.77	0.13	23,600	360	1.5	124	3.4	10.8	1,500	450	250	130	71	91	309	+	"
310	"	15	10:52	215	40	81	240	40	83	24	0.48 2.61	20.27	0.12	30,400	343	1.1	124	3.8	10.7	1,700	800	140	70	91	96	310	—	"
311	"	16	7:15	170	40	76	250	40	84	24	0.50 2.40	17.90	0.15	26,800	387	1.4	124	3.7	10.7	2,700	700	130	80	89	97	311	+	" Run broken into.
312	"	17	7:33	150	28	81	325	40	88	24	0.47 2.18	17.00	0.12	25,500	341	1.3	124	3.7	10.8	1,400	850	140	22	97	98	312	—	" do
313	"	18	3:24	200	30	85	325	45	86	24	0.19 2.29	19.94	0.12	30,000	386	1.3	124	3.8	10.8	2,200	1,500	230	60	96	97	313	+	"
314	"	19	3:17	220	28	87	400	40	90	24	0.19 3.03	24.18	0.12	36,200	453	1.2	124	3.7	10.7	2,100	1,700	300	49	97	98	314	—	"
315	"	20	3:35	280	28	90	375	40	89	24	0.77 3.04	13.45	0.13	20,200	343	1.7	124	3.6	10.8	2,000	1,200	160	50	96	98	315	+	"
316	"	20	17:28	270		......	350	45	87	24	0.75 3.33	12.07	0.10	18,100	356	2.0	124	3.8	10.8	2,400	1,400	110	7	99	99	316	—	"
317	"	21	5:38	260	......	......	325	45	86	24	0.71 3.31	12.22	0.13	18,300	372	2.0	124	3.7	10.8	1,500	1,500	230	60	96	96	317	+	"
318	"	21	17:59	255	......	......	250	45	82	24	0.71 2.89	12.40	0.12	18,600	394	2.1	124	3.9	10.7	1,400	1,300	130	70	95	95	318	—	"
319	"	22	6:30	230	......	......	275	55	80	24	0.71 2.76	7.55	0.13	11,300	390	3.5	123	3.7	10.7	1,400	1,200	2,100	100	92	93	319	+	"
320	"	22	14:11	200	......	......	225	40	82	24	0.71 2.66	1.55	0.11	2,300	412	17.9	117	3.8	10.7	2,200	1,100	1,000	25	98	99	320	—	"
321	"	23	6:01	175	......	......	180	28	84	24	0.71 2.57	10.28	0.13	15,400	319	2.1	123	3.8	10.7	3,000	1,000	100	34	97	99	321	+	"

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System, Filter No. 4.

Number of Run.	Began. Date, 1900-1901.	Began. Hour.	Suspended Matter. Parts per Million. Subsided Water.	Suspended Matter. Parts per Million. Coagulated Water.	Suspended Matter. Per Cent. Removed.	Silica Turbidity. Parts per Million. Subsided Water.	Silica Turbidity. Parts per Million. Coagulated Water.	Silica Turbidity. Per Cent. Removed.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours. Service.	Periods of Time. Hours. Wash.	Quantities of Water. Gallons. Filtered.	Quantities of Water. Gallons. Wash.	Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet. Initial.	Loss of Head. Feet. Final.	Bacteria. Per Cubic Centimeter. River.	Bacteria. Per Cubic Centimeter. Subsided Water.	Bacteria. Per Cubic Centimeter. Coagulated Water.	Bacteria. Per Cubic Centimeter. Filtered Water.	Bacterial Efficiency. Per Cent. Coagulating Basin.	Bacterial Efficiency. Per Cent. System.	Number of Run.	Remarks.
322	July 23	16:26	140	......	......	225	25	89	24	0.72 2.79	10.62	0.10	15,900	277	1.7	124	3.7	10.8	1,700	1,300	180	80	94	95	322	– Agitator.
323	" 24	3:09	170	......	......	250	55	78	24	0.73 2.79	9.60	0.13	14,400	336	2.3	123	3.7	10.7	1,700	1,400	375	34	98	98	323	+ "
324	" 24	13:02	195	...	....	260	70	73	24	0.72 2.62	9.25	0.10	13,900	325	2.3	123	3.7	10.8	2,000	1,500	350	60	96	97	324	– "
325	" 24	22:23	195	......	..	200	65	68	24	0.71 2.48	8.32	0.13	12,500	331	2.6	123	3.6	10.8	2, 00	1,400	550	95	93	95	325	+ "
326	" 25	6:50	195	.....	......	190	45	76	24	0.70 2.50	10.07	0.10	15,100	338	2.2	124	3.8	10.8	1,900	1,700	400		....	......	326	– "
327	" 25	17:00	175	......	..	180	50	72	24	0.72 2.49	13.80	0.15	20,700	439	2.1	124	3.8	10.8	1,900	1,300	400	......	..	......	327	Beginning with run No. 327 all washes + agitator.
328	" 26	6:57	145	.....	.....	200	50	75	24	0.70 2.54	9.53	0.10	14,300	367	2.5	123	3.6	10.8	1,700	1,100	275	110	90	94	328	
329	" 26	19:35	170	......	.....	230	45	81	24	0.72 2.20	11.13	0.15	16,700	403	2.4	123	3.6	10.8	3,600	1,000	160	50	95	99	329	
330	" 27	6:52	180	......	.....	230	50	78	24	0.70 2.29	10.42	0.15	15,600	401	2.6	123	3.8	10.8	850	750	55	50	93	94	330	
331	" 27	17:26	180	......	....	230	50	78	24	2.99	9.00	0.13	14,400	554	3.8	123	3.8	10.8	1,700	750	200	150	80	95	331	Using water from Basin No. 8.
332	" 28	3:10	170	......	......	210	40	81	24	3.00	10.03	0.15	15,000	416	2.8	123	3.8	10.9	1,500	1,000	350	130	87	93	332	
333	" 28	13:21	170	.....	.....	200	35	83	24	0.72 2.45	11.60	0.10	17,400	352	2.0	124	4.0	10.8	1,900	1,300	500	100	92	95	333	
334	" 29	1:15	155	.. ..	....	170	40	77	24	0.70 2.44	11.23	0.15	16,900	362	2.1	124	3.7	10.8	1,400	1,700	550	85	95	94	334	
335	" 29	12:38	155	.....	......	180	40	78	24	0.70 2.45	11.83	0.10	17,800	354	2.0	124	3.8	10.8	1,100	1,500	325	80	95	93	335	
336	" 30	00:34	140	......	......	200	35	83	24	0.71 2.45	14.77	0.13	22,200	488	2.2	124	3.6	10.8	2,000	1,800	425	190	89	91	336	Run broken into. At end of run No. 336 removed ½-in. sand.
337	" 30	22:43	140	......	....	150	50	67	24	0.70 1.96	14.83	0.15	22,250	505	2.3	124	3.7	10.7	2,200	1,100	475	170	85	92	337	
338	" 31	13:42	155	.....	....	150	40	73	24	0.71 [illegible]	11.70	0.10	17,600	363	2.1	124	3.7	10.7	960	900	550	150	83	84	338	

340	"	1	15:41	115	.....	.....	150	45	70	24	1.73	12.85	0.16	19,300	435	2.5	123	3.7	10.7	1,200	6,000	500	80	99	93	340	
341	"	2	4:42	115	......	......	150	28	81	6	0.38 1.60	7.92	0.10	11,900	337	2.8	123	3.7	10.8	900	475	220	65	86	93	341	Beginning with run No. 341 using water from Coagulating Basin No. 3.
342	"	2	12:43	115	.....	....	150	23	85	6	0.38 1.61	9.83	0.15	14,700	392	2.7	123	3.7	10.9	900	550	150	75	86	92	342	
343	"	2	22:18	115	.....	....	150	23	85	6	0.39 1.60	11.88	0.10	17,800	309	1.7	124	3.9	10.8	1,300	1,800	200	350	81	75	343	
344	"	3	10:17	115	......	.....	150	22	85	6	0.38 1.60	8.27	0.10	12,400	337	2.7	123	3.6	10.8	950	1,600	400	100	94	85	344	
345	"	4	1:17	100	......	......	130	22	83	6	0.36 1.61	9.62	0.10	14,400	316	2.2	124	3.8	10.8	700	1,600	400	130	92	81	345	
346	"	4	11:00	100	......	......	130	22	83	6	0.38 1.60	10.60	0.12	15,900	360	2.3	123	3.6	10.8	....	....	65	65	......	......	346	
347	"	4	21:43	100	......	......	130	22	83	6	0.38 1.61	5.55	0.10	8,300	285	3.4	123	3.8	10.8	....	....	65	44	......	......	347	
348	"	5	3:22	100	.. ...	......	130	25	81	6	0.38 1.61	7.33	0.10	11,000	296	2.7	123	3.8	10.8	....	....	....	16	.....	......	348	
349	"	5	10:48	95	......	......	120	23	81	6	0.39 1.60	9.57	0.10	14,400	312	2.2	124	3.6	10.8	... ...	650	....	75	89	......	349	
350	"	5	20:28	95	......	.....	120	30	75	6	0.39 1.58	8.20	0.10	12,300	349	2.8	123	3.8	10.8	....	650	....	......	.. ...	......	350	
351	"	6	4:46	95	....	......	120	30	75	6	0.38 1.53	8.27	0.10	12,400	368	3.0	123	3.8	10.9	....	....	....	70	....	....	351	
352	"	6	21:00	95	......	..	110	28	75	6	0.38 1.50	5.12	0.13	7,700	322	4.2	122	5.1	10.8	400	700	450	275	61	31	352	New Sand.
353	"	7	2:15	95	......	......	120	30	75	6	0.38 1.53	4.55	0.12	6,800	345	5.1	122	5.1	10.8	800	700	375	225	68	72	353	
354	"	7	6:55	95	....	......	120	30	75	6	0.38 1.52	5.22	0.15	7,800	302	3.9	121	4.7	10.9	1,200	700	800	160	77	87	354	
355	"	7	12:15	95	.....	......	90	30	67	6	0.38 1.53	5.92	0.10	8,900	268	3.0	123	4.8	10.8	1,800	1,000	300	190	81	89	355	
356	"	7	18:16	95	......	.....	90	30	67	6	0.38 1.53	6.83	0.10	10,200	284	2.8	123	4.7	10.8	1,100	1,000	700	375	63	66	356	
357	"	8	1:12	75	......	......	110	20	82	6	0.38 1.61	6.23	0.10	9,400	296	3.1	123	4.7	10.8	450	1,000	650	375	63	17	357	
358	"	8	7.32	75	.....	......	110	20	82	6	0.38 1.61	5.48	0.16	8,200	232	2.8	121	4.5	10.8	475	1,000	200	375	63	21	358	
359	"	8	17:00	75	......	....	110	35	68	6	0.38 1.60	5.90	0.10	8,800	322	3.7	123	5.1	10.8	850	1,100	350	450	59	47	359	
360	"	8	23:00	75	.....	......	110	35	68	6	0.37 1.47	5.80	0.10	8,700	312	3.6	123	4.7	10.8	475	700	500	500	29	...	360	
361	"	9	4:54	75	......	......	100	28	72	6	0.38 1.47	5.65	0.08	8,500	263	3.1	123	4.7	10.9	450	700	500	550	21	......	361	
362	"	9	10:38	75	.....	......	100	28	72	6	0.38 1.43	9.23	0.10	13,800	296	2.1	124	4.5	10.8	1,400	800	825	500	38	64	362	
363	"	9	19:58	75	......	......	100	28	72	6	0.38 1.52	7.10	0.10	10 600	271	2.5	123	4.7	10.9	1,600	800	700	1000	......	88	363	
364	"	10	3:18	75	......	......	95	27	72	6	0.38 1.42	6.16	0.10	9,200	222	2.4	123	4.8	10.9	1,700	600	1,000	900	....	47	364	

TABLE LVIII.—Continued.

Summary of the Quantitative Results and of the Efficiency of the American System. Filter No. 4.

Number of Run.	Began.		Suspended Matter. Parts per Million.		Suspended Matter.	Silica Turbidity. Parts per Million.		Silica Turbidity.	Period of Coagulation. Hours.	Average Amount of Applied Sulphate of Alumina, in Grains per Gallon.	Periods of Time. Hours.		Quantities of Water. Gallons.		Percentage of Wash Water.	Net Rate of Filtration. Million Gallons per Acre. Per 24 Hours.	Loss of Head. Feet.		Bacteria. Per Cubic Centimeter.				Bacterial Efficiency. Per Cent.		Number of Run.	Remarks.
	Date, 1900-1901.	Hour	Subsided Water.	Coagulated Water.	Per Cent. Removed.	Subsided Water.	Coagulated Water.	Per Cent. Removed.			Service.	Wash.	Filtered.	Wash.			Initial.	Final.	River.	Subsided Water.	Coagulated Water.	Filtered Water.	Coagulating Basin.	System.		
365	Aug. 10	9:34	75	......	......	95	27	72	6	{0.38 1.42	6.05	0.10	9,100	338	3.7	123	4.6	10.9	1,900	450	1,300	210	53	89	365	
366	" 10	15:43	75	......	......	95	27	72	6	{0.38 1.39	7.48	0.10	11 200	300	2.7	123	4.3	10.8	1,500	450	800	275	39	82	366	
367	" 10	23:18	75	......	......	100	25	75	6	{0.38 1.39	7.75	0.10	11,600	319	2.7	123	4.7	10.9	850	800	300	650	19	24	367	
368	" 11	7:09	75	......	......	100	25	75	6	{0.37 1.39	6.55	0.10	9,800	304	3.1	123	4.5	10.9	800	800	250	110	86	86	368	
369	" 11	13:48	75	......	......	100	25	75	6	{0.37 1.39	7.00	0.10	10,500	293	2.8	123	4.5	10.8	900	850	250	150	82	83	369	
370	" 11	20:54	75	......	......	100	25	75	6	{0.38 1.39	6.38	0.10	9,600	278	2.9	123	4.7	10.8	1,900	900	275	240	73	87	370	
371	" 12	3:23	85	......	......	110	65	41	6	{0.37 1.39	5.54	0.10	8,300	323	3.9	123	4.7	10.8	1,200	1,000	325	160	84	87	371	
372	" 12	9:01	85	......	......	110	65	41	6	{0.38 1.39	6.43	0.10	9,600	304	3.2	123	4.2	10.9	475	1,000	350	80	92	83	372	
373	" 12	21:30	85	......	......	110	65	41	0.25	2.05	2.02	0.10	3,000	285	9.5	119	4.7	10.8	475	500	300	230	74	52	373	
374	" 12	23:37	85	......	......	100	95	5	0.25	2.05	2.66	0.10	4,000	334	8.3	120	4.7	10.8	475	500	300	200	60	58	374	
375	" 13	2:23	75	......	......	100	95	5	0.25	2.10	2.20	0.10	3,100	323	10.4	119	4.7	10.8	475	500	300	130	74	73	375	
376	" 13	4:42	75		......	100	95	5	0.25	2.10	2.63	0.10	3,900	334	8.6	120	4.7	10.8	350	425	250	100	79	71	376	
377	" 13	7 26	75	......	......	100	95	5	0.25	2.10	2.35	0.08	3,500	278	7.9	121	4.5	10.9	275	350	200	75	79	78	377	
378	" 13	9:52	75	......	......	100	95	5	0.25	2.10	2.15	0.10	3,200	284	8.9	120	4.4	10.9	275	325	250	50	85	82	378	
379	" 13	12:07	75	......	......	100	95	5	0.25	2.10	2.18	0.08	3,300	290	8.2	121	4.5	10.8	275	300	275	17	94	94	379	
380	" 13	14:23	75	......	......	100	95	5	0.25	2.10	2.15	0.10	3,200	263	8.2	120	4.5	10.8	275	300	275	25	92	91	380	
381	" 13	16:38	75	......	......	100	95	5	0.25	2.10	2.03	0.10	3,000	289	9.6	119	4.4	10.8	275	300	275	36	88	87	381	
382	" 13	18:46	75	......	......	100	95	5	0.25	2.10	2.10	0.10	3,100	304	9.8	119	4.5	10.8	210	325	325	190	42	10	382	

395	"	15	13:41	90	.....	......	130	20	85	12	1.44	11.62	0.15	17,400	400	2.3	123	4.6	10.8	500	425	150	80	81	84	395
396	"	16	13:00	100	......	......	130	110	15	0.25	2.30	2.12	0.15	3,200	454	14.2	117	4.5	10.8	800	550	170	85	85	89	396
397	"	16	15:16	100	.....	......	130	110	15	0.25	2.30	2.05	0.16	3,100	420	13.5	116	4.4	10.8	550	130	650	100	23	82	397
398	"	16	17:30	100	.. ..	......	130	110	15	0.25	2.30	2.08	0.13	3,100	278	9.0	117	4.4	10.8	550	130	650	150	.....	73	398
399	"	16	19:43	100	......	....	130	110	15	0.25	2.30	2.42	0.10	3,600	237	6.6	120	4.4	10.8	550	600	1,700	170	72	69	399
400	"	16	22:14	100	......	......	130	110	15	0.25	2.30	2.27	0.10	3,400	303	8.9	120	4.3	10.8	550	600	1,700	120	80	78	400
401	"	17	00:36	75	......	......	95	90	5	0.25	2.30	2.20	0.10	3,300	341	10.3	120	4.3	10.8	1,100	1,100	1,500	160	85	85	401
402	"	17	2:54	75	......	......	95	90	5	0.25	2.20	2.45	0.10	3,700	281	7.6	120	4.3	10.8	1,600	1,100	1,400	250	77	86	402
403	"	17	5:29	75	......	......	95	90	5	0.25	2.20	2.72	0.12	4,200	412	9.8	120	4.4	11.0	1,600	1,100	1,400	240	78	85	303
404	"	17	8:12	75	.	......	95	90	5	0.25	2.20	2.22	0.12	3,300	315	9.5	118	4.4	10.8	475	900	1,000	200	78	58	404
405	"	17	10:32	75	......	.....	95	90	5	0.25	2.20	2.03	0.15	3,000	417	13.9	116	4.3	10.7	475	750	650	130	83	73	305
406	"	17	12:40	75	......	......	95	90	5	0.50	2.20	3.03	0.16	4,500	404	9.0	119	4.2	10.7	475	750	650	130	83	73	406
407	"	17	15:52	75	......	......	95	90	5	0.25	2.20	1.16	0.16	1,700	457	26.8	110	4.7	10.7	500	750	650	75	90	85	407
408	"	17	17:13	75	.....	.....	95	90	5	0.25	2.20	1.98	0.10	3,000	360	12.0	119	4.9	10.8	550	750	550	95	87	83	408
409	"	17	19:18	75	....	.....	95	90	5	0.25	2.20	2.90	0.10	4,400	296	6.7	121	4.3	10.8	500	750	425	75	90	85	409
410	"	17	22:18	75	......	.....	95	90	5	0.25	2.20	2.07	0.10	3 100	268	8.6	119	4.1	10·8	500	750	425	75	90	85	410

CHEMICAL ANALYSIS OF EFFLUENT.

The results of chemical analysis of the effluent of the two American systems are given in Chapter VIII. The individual bacterial results have been omitted from this report because there seems no necessity of repeating in detail what has been given in the averages recorded in Tables Nos. LVII and LVIII.

THE LEADING FEATURES ASSOCIATED WITH THE EFFICIENCY AND COST OF OPERATION OF THE AMERICAN SYSTEM OF PURIFICATION RECEIVING PLAIN SUBSIDED WATER, BASED UPON THE RESULTS OF THESE INVESTIGATIONS.

The discussion of many points common to the modified English and American systems was taken up in Chapter IV; it remains, therefore, to discuss the data given above with reference to the cost of construction and operation of the American system to produce a satisfactory effluent, and to deduce an outline of the conditions favoring the most efficient, and at the same time most economical purification by this system. This discussion is taken up as follows:

THE IMPORTANCE OF ECONOMICAL CLARIFICATION, AND THE COMPARATIVE UNIMPORTANCE, FROM A HYGIENIC STANDPOINT, OF THE CONSIDERATION OF THE BACTERIAL EFFICIENCY AND REMOVAL OF ORGANIC MATTER BY THE AMERICAN SYSTEM.

As stated in Chapter I, the unpurified Mississippi River water connot be condemned as a source of supply for New Orleans on account of the numbers and kinds of bacteria contained therein. This is because of the great dilution of the sewage entering the stream, and the time and opportunities which exist for self-purification of the same. On the other hand, the Mississippi River water contains enormous amounts of suspended matter, both silt and clay, amounting on the average to about 2.7 tons per million gallons. How this amount compares with that found in the rivers which supply other American cities may be gathered from the following table, which also illustrates the magnitude of the local problem:

TABLE LIX.

ıowing the Amounts of Suspended Matter in the Unfiltered River Water Supplies of Various American Cities.

CITY.	RIVER.	SUSPENDED MATTER.	
		Parts per Million. River Water.	Tons per Million. Gallons.
,awrence..........	Merrimac..........	10	0.042
.lbany..............	Hudson............	15	0.062
ittsburg...........	Allegheny	50	0.208
Vashington.......	Potomac...........	80	0.333
incinnati	Ohio	230	0.957
,ouisville..........	Ohio	350	1.480
Iew Orleans......	Mississippi.........	650	2.70
t. Louis	Mississippi........	1000	4.16

The Mississippi River water at New Orleans, as the above table ιows, is more turbid than any other water in this country, which has ːen carefully studied, with the exception of that at St. Louis. While ιe latter water, in the average raw condition, is apparently from 50 er cent to 100 per cent more muddy than the local water, yet its mud ːttles so much more readily and completely that, according to available vidence, the New Orleans water after plain subsidence is twice or more s turbid. Accordingly, the local river water is, probably, the most ifficult one of its class to treat, because a larger share of the work ould have to be effected by the processes of coagulation and filtration, hich are not so simple and cheap as plain subsidence.

The problem of the efficient and economical removal of this silt ıd clay by plain subsidence and also by coagulation, before entering e sand layer, is one which has been kept clearly in mind during the hole of these investigations. It was found at New Orleans that lequate bacterial efficiency was obtained, except when new sand, or nd which had not yet become aged, was used in the filters; provided, course, that adequate treatment had been given to remove the ıspended matter.

Generally speaking, given an effluent of good appearance, the acterial efficiency may always be expected to be sufficient.

The organic matter likewise was removed with the silt, and only a nall amount of organic matter remained in the water, as may be seen y inspecting the results of chemical analysis of effluent (Chapter III). This is because of the power the suspended matter has of ısorbing organic matter from solution so that when the clay is re- ɔved the organic matter is to a great extent removed with it; con-

firming the wide spread popular belief that the intimate mingling of clay and organic matter in the water of itself effects a purification of the water.

SOME LEADING POINTS IN THE DISCUSSION OF THE AMERICAN SYSTEM OF PURIFICATION.

The operation of the American system will be discussed largely from the standpoint of the efficient and economical removal of suspended matter, meantime showing how this will necessarily be accompanied by satisfactory bacterial efficiency.

It is convenient to discuss the operation of this system under three headings, as follows:

1. Preparation of the water for filtration.
2. Discussion of the various significant factors from the standpoint of construction.
3. Discussion of the various factors from an operative standpoint.

The two filters were operated with the same applied water for a period of ten days; and were found to be practically identical in their effect upon properly treated water.

The various factors which may affect somewhat, under local conditions, the efficiency and cost of purification by this system are so many and so interdependent that it is necessary to limit the scope of the discussion to certain conditions which local experience has shown to be the most important from a practical standpoint.

1. Preparation of the water for filtration.—It has been conclusively demonstrated in other places that this system of filtration will satisfactorily purify waters of the same general type as the local water, provided, the water has received adequate treatment before filtration. Therefore, to ascertain the exact conditions, which would favor this proper treatment was one of the principal objects of this investigation. The various points under this heading are taken up as follows:

A. LIMIT OF TURBIDITY BELOW WHICH IT IS ADVISABLE TO REDUCE THE WATER IN ORDER TO PREPARE IT FOR SUBSEQUENT FILTRATION.

It is desirable to add coagulant to very turbid subsided water so that after certain periods of supplementary subsidence the water shall have the turbidity best adapted for economical filtration. It is obvious that as the turbidity of the coagulated water increases, within ordinary limits, the cost of washing the filter increases also. On the other hand, it requires longer periods of plain subsidence and of supplementary subsidence with coagulation, and greater amounts of sul-

phate of alumina to secure a lower turbidity of coagulated water. These opposing factors may be most conveniently reduced to cost per million gallons of water filtered, for the purpose of comparison.

The following table indicates approximately the costs of wash water per million gallons, and the periods of service, when operating with a coagulated water having various amounts of suspended matter. These data are obtained from curves prepared from the records of both filters, and with reference to sand adapted to the local water.

TABLE LX.

Showing the Approximate Relation between Turbidity of Filter Influent, Percentage and Cost of Wash Water, and Yield of the Filter between Washings.

Influent.		Wash Water.		Period of Service. Hours.	Yield. Million Gallons per Acre Per Day.
Silica Turbidity. Parts per Million.	Suspended Matter. Parts per Million.	Percentage.	Cost per Million Gallons.		
25	15	1.5	$0.27	29	150
50	30	2.0	.36	21	110
75	45	3.0	.54	13	70
100	60	4.0	.72	10	50
150	90	6.5	1.17	6	30

The cost of wash water is estimated at $18 per million gallons. No allowance is made for the use of filtered water for purposes other than washing the filter.

It is believed from the above table that it is not economical to apply coagulant to reduce the turbidity of the water to below about 50 parts per million, (30 parts of suspended matter per million). It is also believed that considerable saving is effected by reducing the turbidity to below about 75 parts per million, (45 parts of suspended matter per million); but it is an open question what should be the proper turbidity between these general limits to which to reduce the subsided water in order to effect the most satisfactory and economical filtration.

It is a well-known fact that after enough coagulant has been added to effect clarification it takes but a small increased amount to obtain more perfect clarification. The cost of this slight excess has to be balanced against the cost of wash water saved by the procedure. In view of the above, it seems judicious for the purpose of comparison, to assume that coagulant should be added in sufficient amounts to reduce the turbidity of the subsided water to less than about 75 parts per million, (45 parts of suspended matter per million).

B. CHARACTER OF THE RIVER WATER AFTER 12, 24, 48 AND 72 HOURS PLAIN SUBSIDENCE.

The character of the suspended matters in the river water, both before, and after being subjected to different periods of plain subsidence, is given in the following table. In this table are given the average monthly amounts of silica turbidity and suspended matter contained in the Mississippi River water before and after different periods of plain subsidence. The estimated annual and maximum weekly average amounts of suspended matter are also given:

TABLE LXI.

Showing the Average Monthly and Maximum Weekly Amounts of Silica Turbidity and Suspended Matter Contained in the Mississippi River Water Before and After Various Periods of Plain Subsidence, for the Normal Year. Parts per Million:

Month.	River.		12 Hours.		24 Hours.		48 Hours.		72 Hours.	
	Silica Turbidity.	Suspended Matter.	Silica Turbidity.	Suspended Matter.	Silica Turbidity.	Suspended Matter.	Silica Turbidity.	Suspended Matter.	Silica Turbidity.	Suspended Matter.
January	385	415	275	250	245	210	210	170	200	150
February	640	700	480	435	425	350	380	300	350	265
March	1,150	1,240	850	755	750	625	660	525	600	460
April	1,425	1,540	1,100	970	975	825	875	700	775	590
May	1,350	1,460	1,025	925	925	775	815	650	750	575
June	920	1,000	700	615	615	525	550	440	500	385
July	600	650	400	375	375	310	320	250	300	225
August	410	445	290	260	260	220	225	180	210	160
September	290	315	230	210	210	180	180	145	170	125
October	185	200	170	150	150	125	120	95	120	90
November	160	175	130	110	110	90	90	70	90	70
December	260	280	160	145	140	120	120	95	120	90
Average	650	700	485	435	430	360	380	300	350	265
Maximum Weekly	....	3,000	....	2,000	....	1,650	....	1,400	....	1,200

C. REQUIRED QUANTITIES OF COAGULANT FOR DIFFERENT PERIODS OF PLAIN SUBSIDENCE.

The following amounts of coagulant would be required on the average in order to obtain a water after different periods of coagulation and supplementary subsidence, which would have a turbidity of less than about 75 parts per million (45 parts of suspended matter per million). The results show that the time of supplementary subsidence was a factor, as well as the amount of sulphate of alumina used as a coagulant, the same amount of coagulant being somewhat more effective

in reducing turbidity with longer than with shorter periods of supplementary subsidence. The difference, however, was too slight to be taken into consideration in the estimates when the period of coagulation exceeded 12 hours.

The amounts of coagulant estimated to be required for waters containing different amounts of turbidity are given in the following table:

TABLE LXII.

Showimg Estimated Amounts of Coagulant Required for Different Degrees of Turbidity.

Subsided Water—Parts per Million.		Probable Average Amounts of Sulphate of Alumina, Grains per Gallon.
Silica Turbidity,	Suspended Matter.	
100	90	1.90
150	135	2.25
200	180	2.50
250	225	2.70
300	270	3.00
350	315	3.30
400	360	3.60
450	405	3.85
500	450	4.10

At times these amounts of coagulant would be exceeded by 25 per cent; at other times they could be decreased 25 per cent, according to the character of the suspended matter contained in the river water.

TABLE LXIII.

Showing Amounts of Coagulant Required for Different Periods of Plain Subsidence and Different Periods of Coagulation.

Period of Plain Subsidence.	Sil. Turbidity, Parts per Million.	Susp. Matter, Parts per Million.	Amounts of Sulphate of Alumina, Grains, per Gallon. Period of Coagulation.		
			6 Hours.	12 Hours.	24 Hours.
12 hours.	485	435	4.35	4.05	4.05
24 hours.	430	360	4.00	3.80	3.80
48 hours.	380	300	3.70	3.50	3.50

It will be noticed in the above table that the same amounts of coagulant are estimated as necessary for a 12 and 24-hour period of coagulation, respectively. It is assumed in this connection that a second application of coagulant would be necessary after the water

had been settled for 24 hours in a coagulating basin, while it is believed that, as a rule, enough masses of suspended matter would be left in the water after 12 hours of treatment to allow the further proper clarification of the water by filtration without a second application of coagulant. It so happens that the saving which would be effected in the one case just about balances the amount which, it is estimated, would have to be used in the other case, hence the agreement of quantities.

D. COMPARISON OF THE FACTORS OF COST PER MILLION GALLONS OF FILTERED WATER FOR DIFFERENT PERIODS OF PLAIN SUBSIDENCE AND TURBIDITY OF COAGULATED WATER OF LESS THAN 75 PARTS PER MILLION.

Below are given the various data for the comparison of the factors of cost associated with the various periods of plain subsidence. These data need some explanation as follows:

The cost of coagulant is taken at $25 per ton. The capital charges on the subsiding basins are taken at 5 per cent per annum, while the cost of construction of basins is assumed to be the same as for System No. 2, namely, $6,000 per million gallons daily capacity for open basins, and $7,000 for basins with shaded walls. (See pages 133 and 134).

A.—PERIOD OF PLAIN SUBSIDENCE EQUALS 12 HOURS.

Silica Turbidity of Subsided Water Equals 485 Parts per Million.

Period of Coagulation. Hours.	Cost of Coagulant.	Capital Charges on Subsiding Basin.	Capital Charges on Coagulating Basin.	Total.
6	$7.80	$0.41	$0.24	$8 45
12	7.25	.41	.48	8.14
24	7.25	.41	.96	8.62

B.—PERIOD OF PLAIN SUBSIDENCE EQUALS 24 HOURS.

Silica Turbidity of Subsided Water Equals 430 Parts per Million.
Suspended Matter in " " " 360 " " "

Period of Coagulation. Hours.	Cost of Coagulant.	Capital Charges on Subsiding Basin.	Capital Charges on Coagulating Basin.	Total.
6	$7.16	$0.82	$0 24	$8.02
12	6.90	.82	.48	8:20
24	6.90	.82	.96	8.68

C.—PERIOD OF PLAIN SUBSIDENCE EQUALS 48 HOURS.

Silica Turbidity of Subsided Water Equals 380 Parts per Million.
Suspended Matter in " " " 300 " " "

Period of Coagulation. Hours.	Cost of Coagulant.	Capital Charges on Subsiding Basin.	Capital Charges on Coagulating Basin.	Total.
6	$6.62	$1.64	$0.24	$8.50
12	6.26	1.64	.48	8 38
24	6.26	1.64	.96	8.86

E. THE ECONOMICAL LIMIT OF PLAIN SUBSIDENCE WITH THE MAXIMUM AND MINIMUM ESTIMATED AMOUNTS OF COAGULANT REQUIRED.

The experience of these investigations has shown that while a 6-hour period of coagulation would be adequate to prepare the water for filtration satisfactorily during a greater part of the year, it would be a very short and expensive period to employ during extreme high water, as its use would entail the addition of very large amounts of coagulant. The difference between the estimated cost of a 12-hour period of coagulation and a 6-hour period, is within the limits of accuracy of the data, and experience has shown that this basin capacity would be adequate to treat satisfactorily the water at all times.

In view of the above it seems that the best arrangement of basins would be that which would provide for a period of coagulation of about 12 hours, preceded by a 12-hour period of plain subsidence.

In considering the economical limits of subsidence the fact was recognized that the margin of alkalinity in the river water is so large that any amount of coagulant required, even for very short periods of coagulation, are perfect feasible and safe.

F. NOTES ON THE SPECIAL FACTORS RELATED TO THE PREPARATION OF THE RIVER WATER FOR FILTRATION.

a. Kind of coagulant.—Sulphate of alumina was used, as is described in Chapter V, Page 115.

b. Arrangements for its application and mixture with the Mississippi River water.—The coagulant was added to the water by means of perforated pipes situated in the coagulating troughs. The coagulant was fed into the water as it flowed across the pipe. The arrangements in general were identical with those employed in System No. 2, Pages 56-59.

c. Basin baffles.—All the basins of this investigation were provided with baffles. These baffles prevented the direct passage from inlet to outlet of the water in the coagulating basins and facilitated precipitation.

d. Basin cleaning.—The basins were cleaned twice, once during April and once at the end of the investigation. The coagulated matter was semi-fluid and was washed out of the basins without difficulty.

e. Basin covers.—At the beginning of the investigations the coagulating basins were protected from the direct rays of the sun by a shed with open sides. This was removed on June 7th in order to study the effect of light upon algæ growths in the basins. Only in one instance, and that in the case of System No. 4, where a 24-hour period of coagulation obtained, were algæ growths present in sufficient quantity to affect appreciably the character of the effluent. It is believed that many of the algæ growths were induced by the presence of wood used in the construction of the basins.

2. Discussion of Factors From the Standpoint of Construction.

A. construction of the sand layer.

a. Size of sand grains.—Much attention was directed toward the determination of the best size of sand to use with the American filters of these types. Five sizes of sand were used, as follows:

Sand Number.	Effective Size. Millimeters.	Uniformity Co-efficient.
1	0.54	1.30
2	0.385	1.48
3	0.34	1.41
4	0.25	1.80
5	0.18	1.83

These sands were used at different times as shown above in the list of periods of operation. They affected the operation of the filter in various ways as might be expected when the great range of their effective sizes is taken into account. With the coarser sands, No. 1 and No. 2, the filter operated until the coagulated masses broke through the filter and caused the effluent to be turbid before the available loss of head was utilized; with the finer sands, No. 4 and No. 5, the filter clogged quickly and had to be washed because the available loss of head was utilized, the effluent being clear at the time of washing, and with No. 3 sand the mean of these conditions was obtained.

The minimum loss of head ranged from 3.0 to 10.8 feet, under different conditions.

Quantities of water which are passed through a sand layer depend to some extent upon the age of the sand; a sand which has been in use some time passing less water than a new sand. This is because of

accumulations on the sand grains themselves which increase the friction of the sand layer.

It is obviously most economical to use a sand which shall be just fine enough to permit the available head to be utilized without being too coarse to permit the breaking through of the flocculent coagulated masses, or too fine to cause clogging before the loss of head reaches the maximum.

The size of the sand affected the length of the period of service about as follows, based on the average available data:

Sand Number.	Effective Size. Millimeters.	Period of Service Hours.
1	0.54	19.5
2	0.385	19.5
3	0.34	31.6
4	0.25	9.4
5	0.18	6.4

b. Uniformity of sand.—The size of the sand is not the only factor to be considered; the uniformity co-efficient and the percentage of fine clay particles must also be taken into account. The process of washing tends to stratify the sand in the filters, whether agitation is employed or not, hence the size of the surface layer of the sand rather than the effective size of the whole sand layer may sometimes determine the true effective size. For example: a varied sand having a high percentage of fine particles would cause the filter to clog much sooner than would a uniform sand of much smaller effective size. A concrete example of this difference in sand may be given as follows:

Sand No.	Effective Size. Millimeters.	Uniformity Co-efficient.	Percentage finer than No. 80 sieve: 0.237 m. m.
1	0.180	1.80	23.8
2	0.184	1.30	58.7

If only the size and uniformity coefficient were taken into consideration, the second sand would be better for American filters, but owing to the high percentage of fine particles contained, it would clog more rapidly than the first sand, as was proven by actual trial. After August 17th two different sands were put separately into Filter No. 3 and after being in use for two or three weeks, the filter was washed, with air agitation, and samples of sand were taken at different depths. These samples were analyzed and compared with the analysis of the average samples of the whole sand layer. The size of the lower layer of sand is affected by the presence of gravel brought up during the washing.

TABLE LXIV.

Showing the Degree of Stratification of Sand in the Filter.

A. First Experiment.

Depth of Sample.	Effective Size. Millimeters.	Uniformity Co-efficient.	Percentage finer than No. 80 sieve: 0.237 m. m.
Average Sample....	0.360	1.40	0.19
Surface................	0.237	1.30	10.20
1 inch.........	0.322	1.14	0.40
3 "	0.400	1.28	0.17
6 "	0.360	1.41	1.74
12 "	0.430	1.39	0.68
24 "	0.419	1.48	0.29

B. Second Experiment.

Average Sample....	0.309	1.52	0.50
Surface................	0.213	1.22	25.00
1 inch................	0.226	1.33	23.00
3 "	0.289	1.16	0.60
6 "	0.370	1.11	0.25
12 "	0.385	1.35	0.25
24 "	0 415	1.56	....
36 "	0.405	1.60	0.24

The sand used in the second experiment, was made by mixing the sand used in the first experiment, with equal quantities of sand which had an effective size of 0.18 m. m. It will be noticed that the effective sizes of the two sands are at the limits of the range of sizes considered to be most suited to the purification of the Mississippi River water. The sand used in the second experiment, however, was not at all satisfactory from a practical standpoint and had the same effect upon the operation of the filter as did sand No. 5, which had an effective size of only 0.18 m. m.

These experiments also indicate that it would be possible to remove the finer particles from the sand layer by washing the filter and removing the top layer of sand by scraping.

Sand often contains a few large particles, which on account of their great weight, affect the percentage passing through the various sized sand sieves, and therefore the uniformity co-efficient as determined; the presence of a limited amount of these large particles, however, (gravel,) seemed to have no effect upon the operation of these filters.

From the above evidence it seems that for efficient and economical operation of this type of filter, the sand should not have more than 1 per cent finer than 0.20 m. m. and not more than 1 per cent coarser than 1 m. m. Under the above conditions, the sand should have an effective size, varying between 0.30 and 0.40 m. m., preferably averaging

about 0.35 m. m., and a uniformity co-efficient of less than 1.5. This means, approximately, that the sand should pass through a sieve having 15 lineal meshes and be retained by a sieve having 80 lineal meshes to an inch.

c. Effect of age upon the efficiency of the sand layer.—The age of the sand had a very slight effect upon the efficiency of the filter for clay removal, but a marked effect upon the bacterial efficiency. It seemed to be true that at some time in the period during which the sand was in use the filter failed to give satisfactory bacterial results on account of the bacteria—mostly one or two harmless species—which occurred in the sand layer*. The time of the appearance of this disturbance varied with the temperature and the amount of vegetable organic matter contained in the sand. Some of the sands were not in use long enough to overcome these growths, while one sand after a period of good efficiency suddenly developed large growths which disappeared later, as in the case of the other sands. Growths also developed when the filters were idle. Of course, these phenomena have little bearing upon the real hygienic efficiency of the plant; but they cannot be passed over without explanation. It is believed that these growths would be largely prevented in practice by the removal from the sand of the larger particles of vegetable matter by sieving, though it seems likely that limited growths of bacteria would occur until the sand layer had aged, or until the particles of vegetable matter had become eliminated by disintegration, by attrition, and by repeated washing of the sand layer. The form which was most often observed in this connection was a very small motile liquefying bacillus which did not ferment sugar solutions with the production of gas. It was non-pathogenic to guinea pigs.

It should be stated under this heading that at no time was B. coli communis or B. enteritidis sporogenes found in the effluent of this system, and even harmless gas forming bacteria were practically absent; absent entirely from broth cultures containing phenol, which we tested.

d. Kind of sand.—Local sand from the shore of Lake Ponchartrain or the Mississippi Sound would be suitable for use in the filters. Mississippi Sound sand is preferred on account of its greater freedom from both organic matter and clay.

e. Depth.—With the local water a depth of 2.5 feet seems to be satisfactory. It might be well, however, to increase this depth to about 2.75 feet in order to provide for sand which would be unavoidably lost during the first few washings.

*NOTE.—By R. S. Weston, March 14th, 1903: "Recent experience at other plants in practice indicates that the gravel layers are responsible for most of these bacterial growths, and furthermore, that they disappear in properly washed filters after a few weeks of operation."

B. THE EMPLOYMENT OF GRAVEL LAYERS IN THE FILTER.

The use of gravel in the filters permits the use of a coarser strainer than would otherwise be possible and avoids the clogging and consequent cleaning of the finer strainers such as were used in Filter No. 4. This gravel should be very uniform and of such size as would not allow the sand to penetrate into it to any great depth.

In Filter No. 3 the lowest foot of sand was found to contain a little gravel which had been displaced during washing.

Depth of Gravel.—Experience on this point is very limited, but it seems as if a depth of about 4 inches above the tops of the strainers would suffice.

C. DISTANCE OF SAND SURFACE FROM OVERFLOW GUTTER.

The distance of the sand surface from the overflow gutter in practice, is determined largely by the size of the sand, provided a slight excess of sand is put into the filter at the beginning of operations. With sand of 0.35 to 0.40 millimeters, effective size, a distance of about 10 inches would be satisfactory.

D. DISTRIBUTION OF WASH WATER.

The two systems of distribution of wash water—by pipe and by double bottom—in use, during this investigation, served their purpose equally well as far as can be judged from the operation of small filters. If possible, the openings in the strainers themselves should occupy a position with respect to the sand layer which would prevent the accumulation of unwashed sand or gravel on the bottom of the filter between the strainers. If the strainers were placed at the bottoms of pyramidal depressions in the floor of the filter, with the high points between these depressions situated midway between the strainers, the possibility of incompletely washing the sand between the strainers would undoubtedly be overcome.

It has been found in practice that the fine perforated metal strainers clog with more or less ease; therefore the employment of a coarser strainer and a layer of gravel to prevent the loss of sand seems advisable.

E. AGITATION OF THE SAND LAYER.

A. AIR METHOD.

a. Distribution of Air.—Air was distributed in a satisfactory manner by a system of pipes within the wash water system. The effectiveness of the air method of agitation depends upon the uniform distribution of air. If air is not distributed with uniformity the level

of the gravel layer becomes displaced to the detriment of the efficiency of operation. It is believed that uniform distribution of air could be accomplished in practice by a similar system of pipe distribution.

b. Amount of Air.—About 5 cubic feet of air per minute per square foot of sand surface should be provided to agitate the sand layer.

c. Projection of the gravel into the sand by air currents.—The use of air projects more or less gravel into the sand layer. The most of this returns to the bottom of the filter before the end of the application of wash water. However, the gravel does not perfectly relevel itself, but exhibits a somewhat undulating surface due to the variations in the velocities of the air and water currents in different parts of the bed.

B. MECHANICAL AGITATOR METHOD.

This method is too well known to need description. In practice, rakes should reach as near the bottom of the sand layer as possible, and should be withdrawn from it after the washing.

a. Relative merits of air and mechanical agitator methods.—With the mechanical method of agitation, however, the rakes and water are used simultaneously, while with arrangements now in use, air and water cannot be applied together effectively, without causing prohibitive losses of filtering material through the waste-water outlet. Therefore, the period of washing is slightly increased when the air method is used. On the other hand, the strainer system arranged for the application of air must necessarily provide for its distribution and would seem to be more costly and more complicated than if arranged for the use of a mechanical agitator. The air method of agitation permits the construction of rectangular filters, thereby effecting much economy of space; but the same effect is gained in the Louisville designs, by means of special agitators. It therefore seems that the choice of methods of agitation should depend largely upon their respective costs of construction as they both seem to be equally efficient.

b. On the advisability of omitting agitation during washing.—One feature which has been associated with the air method of washing has been the presence of a layer of gravel to support the sand. However, this gravel layer is a factor which is more closely connected with the construction of the strainer system and could be used with either or without any method of agitation. The following average results of operation covering the period between June 13th and July 26th, show the effect of operating the filters with and without agitation, the use of air and the rakes, respectively, being omitted on alternate runs.

TABLE LXV.

Showing the Effect on the Leading Results of Operation of Washing the American Filters, With and Without Agitation, by Both the Air and Mechanical Agitator Methods.

A. AIR METHOD. NO. 4 SAND.

Procedure.	Loss of Head. Initial.	Loss of Head. Final.	Period of Service. Hours.	Percentage of Wash Water.	Bacterial Efficiency of Filter.
With air.............	3.2	10.75	14.00	2.48	89.0
Without air.........	3.2	10.76	13.77	2.92	89.0

B. MECHANICAL METHOD. NO. 3 SAND.

With agitator.......	2.6	10.70	25.89	2.00	88.5
Without agitator...	2.6	10.70	28.22	1.73	91.4

C. MECHANICAL METHOD. NO. 4 SAND.

With agitator.......	3.6	10.80	13.30	2.07	91.2
Without agitator...	3.6	10.80	12.70	2.06	88.0

Therefore, the data of this investigation, as far as they go, show no reason why any system of agitation should be employed. However, this is hardly conclusive evidence because it is impossible to generalize in this respect from the small filters of this investigation to the large filters of practice, as it is believed that the more efficient stirring of the sand layer by water currents alone could be effected in the small round filters than in the larger ones; and also because there was no opportunity during this investigation to judge how permanent the satisfactory washing would be in view of possible accumulations in the sand layer itself after a considerable period of operation.

Available Head.—According to the data collected during this investigation, and other local evidence, the loss of head as a general proposition may be carried economically to about 8 feet in excess of the initial loss of head. This means that with a suitable and efficient sand layer the difference in level between the surface of the water on top of the filter and in the controller could be made about 10 feet and under certain conditions could be carried to 12 feet.

ͻME CONSIDERATIONS WHICH AFFECT THE ECONOMICAL LIMITS TO WHICH RATE OF FILTRATION AND LOSS OF HEAD CAN BE CARRIED IN AMERICAN FILTERS.

In some localities the increased loss of head carries with it but ttle increased cost of construction, and therefore this cost, plus the ıcreased cost of pumping may be more than offset by the decreased ͻst of operation due to longer periods of service between washings. [ew Orleans conditions, however, do not allow the placing of very eavy structures upon the soil without expensive foundations, and the ost of washing would be materially less per million gallons of effluent vith properly prepared water than would be the case in other places vhere shorter periods of service and larger percentages of wash water re advisable from the standpoint of efficiency and economy.

The above factors also affect the rate of filtration; for while it nignt be increased 25 per cent without decreasing the efficiency of urification, the available head would be lessened unless the cost and ifficulty of construction were materially increased.

3. Rate of Filtration.—A rate of 125 million gallons per acre per I hours on the average, seems adapted to local conditions. This rate uld be increased 25 per cent in any emergency without harmfully fecting the character of the effluent, other things being normal.

Rate of Application.—The normal rate of application of wash ater was from three to four times the rate of filtration. In practice is part of the plant should be designed to furnish water at a maxium of five times the rate of filtration, or at the rate of 625 million llons per acre per 24 hours.

Pressure of wash water.—The net pressure of the wash water at e strainer system when washing at four times the rate of filtration as about 10 feet. (4.5 pounds).

'ECIAL FACTORS ASSOCIATED WITH THE OPERATION OF THE PLANT.

In order to operate the plant conveniently and systematically, the llowing points would have to be observed.

Time required for washing.—The available evidence indicates that ͻout 6 minutes application of wash water sufficed to cleanse the sand yer. At times this period was increased to 8 or 9 minutes, while at ther times 4 minutes were found to be sufficient. The period of ashing, in practice, including the opening and closing of the valves—hich should be constructed with a view to their quick opening and losing—would probably average 10 minutes per washing.

Frequency of washing.—With the optimum sand, and with a ͻagulated water of optimum turbidity, the filters would have to be

washed not oftener than once every 12 hours, on an average. Much longer runs could be easily secured by increasing the degree of coagulation, but available evidence does not point to the economy of such a procedure.

Disposal of waste wash water.—It would seem best, under local conditions, to discharge the wash water by gravity where it can be most cheaply disposed of. It does not seem to be advisable to return the water to the subsiding basins.

Wastage of filtered water directly after washing.—The wastage of filtered water directly after washing, under ordinary conditions, would be neither necessary nor desirable. Provision, however, should be made for wasting the filtered water to provide for possible emergencies. It would be a desirable refinement, if practicable, to use the first portions of filtered water after washing one filter, as wash water for another filter. This, however, would necessitate a somewhat more complicated piping system and the slight benefit derived might not be commensurate with the cost.

The relation of proper supervision and attendance to the operation of the filters.—With a 40 million gallon plant to purify the Mississippi River water, the cost of sulphate of alumina alone would range from $72 to $450 per day, according to the present process. Therefore, it is important, on the ground of safety and economy, that the plant should be well managed; as may be understood after the most casual consideration of the situation.

In addition to the force required for the operation of the modified English system, independent of scraping, it would be necessary to have one more laborer on duty and it should be provided that the filter foreman should be a mechanic who is competent to make all the ordinary repairs. This would accordingly increase the cost of supervision and attendance to $1.16 per million gallons of filtered water.

Efficiency of the System.—A plant constructed on the basis of the above outline would purify the Mississippi River water to such a degree that a clear, hygienically satisfactory water would be furnished at all times.

For the purpose of estimates, the cost of plain subsiding reservoirs; coagulating basins; clear water reservoir; cleaning basins; pumping and repairs, are taken the same as for the modified English system as is given in the preceeding chapter, Pages 133, 134.

The cost of the American filters, including filter house, laboratory and necessary appurtenances is estimated at $7,000 per million gallons daily capacity. On the above basis, the estimated cost of a plant having a net capacity of 40 million gallons daily would be $280,000.

It is estimated that the total cost of the purification plant, inciuding a 12-hour subsiding basin, a 12-hour coagulating basin, American filters, and clear water basin would be $700,000; on the same bases as used in Chapter V. At 5 per cent per annum the capital charges, interest and depreciation, would be $2.40 per million gallons of water filtered.

It is estimated that 4.5 grains of coagulant per gallon would be required on an average. This amount includes about 0.5 grain per gallon, in addition to a liberal allowance based on the results of these investigations, as a factor of safety.

The amount of wash water required is estimated at 4 per cent. This includes the filtered water used about the plant for cleaning basins and general purposes.

It is estimated that about $3,000 would have to be spent each year to buy the necessary small supplies needed to keep the plant in perfect repair.

TOTAL COST OF PURIFICATION.

The total estimated cost of purification by a plant of 40 million gallons daily capacity per million gallons purified by such a system as outlined above, is itemized as follows:

Capital charges, basins and filters	$ 2.40
Double low lift pumping, including capital charges and operation	2.23
Sulphate of Alumina	8.04
Wash water	.72
Supervision and attendance	1.16
Cleaning basins	.25
Miscellaneous supplies	.20
	$15.00

CONCLUSION.

These investigations have demonstrated that the American system is adaptable to the purification of the Mississippi River water and at an estimated cost of $15.00 per million gallons, an amount somewhat less, both as to first investment and for total cost per million gallons of filtered water, than in the case of the modified English system.

CHAPTER VII.

Final Resumé and Conclusions.

This chapter is an abstract of what goes before, omitting those points which are of a purely technical nature.

CHARACTER OF THE MISSISSIPPI RIVER WATER.

The Mississippi a very muddy stream.—The Mississippi River is a very muddy stream, containing about 600 parts of suspended matter, silt, clay, etc., per million, on the average. This is equivalent to 2.7 tons of solid matter in each million gallons of water. During seasons of flood this amount of suspended matter may be increased fourfold.

The Mississippi River practically free from evidences of pollution.—Owing to the small population per square mile on its water shed; the small amount of sewage entering during its flow through the last few hundred miles of its course; the vast volume of the stream itself, and the opportunities which are afforded for self purification, the Mississippi River is practically free from evidences of sewage pollution and the germs of infectious disease. Furthermore, the suspended matter absorbs the greater part of the organic matter contained in the water so that its removal is accomplished with the removal of the suspended matter.

Complete clarification a concomitant of successful water purification at New Orleans.—The economical clarification of the water by the removal of the clay and other matter is, therefore, indirectly the chief end of any system of water purification at New Orleans, because experience has shown that this removal of clay is accompanied by an adequate removal of bacteria; thereby guaranteeing protection against the germs of disease which at some time might perhaps be present in the river water.

Methods of purification.—Three general steps in the systems for clarification and purification have been considered in various combinations, as follows:

1. Plain subsidence in basins for several days.
2. Supplementary subsidence in basins, with the aid of coagulant.
3. Filtration, either at a slow rate, through sand beds—English filters; or at a rapid rate through filters provided with mechanical devices for cleaning the sand—American system.

1. PLAIN SUBSIDENCE.

Relative fineness of the suspended matter.—The suspended silt and clay in the Mississippi River water at New Orleans contains much very fine material. This is probably because of the opportunity afforded for sedimentation of the larger particles, during ordinary stages of the river, on the bed of the river itself. These larger particles then become broken into, or worn to, sizes which can be carried down stream by the lower velocities which obtain in the last few hundred miles of the course of the river.

An idea of how fine these particles are may be obtained by comparing the approximate percentage of suspended matter removed from the local water for 24 hours of plain subsidence with that removed from the muddy waters of other localities for the same period of subsidence, as follows:

Locality.	River.	Estimated Percentage Removal of Suspended Matter in 24 Hours.
Kansas City.......	Missouri.............	82
Cincinnati	Ohio..................	62
New Orleans.....	Mississippi	45

Plain subsidence inadequate to prepare water for filtration at all times.—On account of the large amount of fine clay particles, the suspended matter is held in suspension indefinitely, and cannot be removed on the average by any practical periods of plain subsidence, even by periods of a week or more.

English filters and plain subsidence.—When this subsided water is filtered at slow rates through thick layers of fine sand, a satisfactory clarification and purification results for a portion of the time. However, this system would produce muddy effluents for months at a time, and what is more of a factor, the cost of cleaning and removing the clogged sand layers would be prohibitively excessive.

2. SUPPLEMENTARY SUBSIDENCE WITH THE AID OF A COAGULANT.

Necessity of coagulant.—Since the fine particles of suspended matter cannot be removed by plain subsidence, it is necessary to add something to the water to bring them together in aggregates or groups which of themselves would have a subsiding value great enough to cause them to settle within a reasonable period. Sulphate of alumina can be used for this purpose, and when added to the water forms a perfectly insoluble gelatinous precipitate, which, uniting with the clay, causes it to gather into flocks or aggregates which settle much more rapidly than the diffused clay particles themselves. This precipitate

also has the power of attracting, enveloping. or absorbing stray particles of suspended matter, including bacteria, so that the water by this method of coagulation and supplementary subsidence can be made fairly clear.

Difficulty of removal of last traces of turbidity by coagulant.—In practice, water which has been purified by plain subsidence followed by supplementary subsidence with a coagulant is, strictly speaking, never perfectly clear. This is because it is difficult to remove the last traces of turbidity by this process alone. Indeed, it is much more satisfactory to make the final step in the clarification and purification process by the use of a suitable filter.

3. METHOD OF FILTRATION.

Two kinds of filters can be used for this final clarification and purification of the effluent of the coagulating basins, namely, the English and American filters. These filters need but little explanation in this chapter. The English filter, as is well known, consists of a bed of sand through which the water, without coagulation, but after being subjected to plain subsidence, filters at a slow rate; while the American system treats the water after both plain subsidence and supplementary subsidence with the aid of a coagulant, and filters it at a rapid rate through a bed of sand which is intermittently freed from matter which obstructs the passage of water, by reversed currents of water, and by agitation. In the English filter the accumulated matter which clogs the filter is removed by draining and scraping.

The main features of the two filters, however, are compared as follows:

	English Filters.	American Filters
Construction	Covered.	Open.
Area of units	About 1 acre.	15x24 feet.
Area of 40 million gallon plant	10 acres.	0.82 acres.
Net yield or rate of filtration, million gallons per acre, per 24 hours	4.	125.
Depth of sand, inches	36.	30.
Depth of gravel, inches	12.	4.
Underdrain system	Drain tiles and conduits.	Pipe system or double bottom and metal strainers.
Clogged sand layer cleaned by	Draining and scraping.	Washing with reversed currents of filtered water until cleaned.
Vertical height of structure	14 feet.	15 feet.
Relative bacterial efficiency, and relative efficiency for clay removal	Satisfactory.	Satisfactory.

BOTH FILTERS APPLICABLE.

Both filters would be applicable to the purification of the Mississippi River water, provided suitable arrangements for plain subsidence and supplementary subsidence with the aid of a coagulant are provided.

The sizes and arrangements of the two systems of purification may be compared as follows:

	Modified English System.	American System.
Total daily capacity of plant, gallons.....	40,000,000.	40,000,000.
Capacity of plain subsidence basin in hours' flow..............	12	12
Capacity of coagulating basin in hours' flow	24	12
Average amount of coagulant, grains per gallon	3.7	4.5
Coagulant used..................................	Practically continually.	Continually.
Approximate first cost of plant........	$1,260,000.	$700,000.
Total estimated cost of purification per million gallons, including interest, depreciation and operating expenses, as well as pumping water from river to suction of high lift pumps.............	$16.46	$15.00

It is seen that the American system is less expensive to construct than the modified English system by more than $500,000.

Selection of system best adapted to local conditions.—Either filter would be adapted to the purification of the Mississippi River water, and the decision as to which would best suit local conditions should be dependent upon the cost per million gallons of filtered water, taking into consideration the difference in first cost.

In total first cost the American system is fully 25 per cent cheaper than the modified English system when estimates are made on the same basis.

Careful supervision necessary with both systems.—Both systems require careful supervision and attention, as is obvious.

FINAL CONCLUSIONS.

Taking into consideration all the available evidence, it is concluded that the American system is best adapted to the purification of the Mississippi River water at New Orleans.

Respectfully submitted,

ROBERT SPURR WESTON,

Resident Expert.

New Orleans, La.,

January 15th, 1902.

CHAPTER VIII.

ADDITIONAL DATA.

TABLE LXVII.

Conversion of Statements of Chemical Composition.

	Grains per U. S. Gal. (231 cu. in.)	Grains per British Gal. (277 Cu. In.)	Parts per 100,000.	Parts per 1,000,000.
1 grain per U. S. gallon	1.	1.20	1.71	17.1
1 grain per British gallon	0.830	1.0	1.43	14.3
1 part per 100,000	0.580	0.70	1.	10.0
1 part per 1,000,000	0.056	0.07	0.10	1.

TABLE LXVII.

Equivalents of Various Measures.

	U. S. Gallons.	Imperial Gallons.	Liters.	Cubic Feet.	Cubic Meters.	Cubic Inches.	Pounds, Avoirdupois. (Water at 0° C.)
1 U. S. gallon	1.	0.8311	3.78520	0.13368	0.003785	231.	8.3388822
1 imperial gallon	1.20032	1.	4.54346	0.16046	0.004543	277.274	10.
1 liter	0.26419	0.22010	1.	0.03532	0.001	61.0271	2.204737
1 cubic foot	7.48015	6.23210	28.31529	1.	0.028315	1.728	62.37916
1 cubic meter	264.18657	220.09671	1000.	35.31661	1.	61027.0963	2204.737
1 cubic inch	....	....	....	....	....	1.	0.036099

TABLE LXVIII.

Approximate Equivalents of Various Measures of Rate of Filtration.

	Million U. S. Gallons per Acre. Per 24 Hours.	Million British Gallons per Acre. Per 24 Hours.	U. S. Gallons per Square Foot. Per Hour.	British Gallons per Square Foot. Per Hour.	Cubic Feet per Square Yard. Per Hour.	Vertical Velocity in Inches. Per Hour.	Vertical Velocity in Millimeters. Per Hour.	Vertical Velocity in Meters per 24 Hours. Cubic Meters per Square Meter per 24 Hours.
1 million U. S. gallons per acre, per 24 hours	1.	0.833	0.96	0.80	1.15	1.53	39.0	0.935
1 million British gallons per acre, per 24 hours	1.200	1.	1.15	0.96	1.38	1.84	46.8	1.122
1 U. S. gallon per square foot, per hour	1.045	0.870	1.	0.83	1.20	1.60	40.7	0.978
1 British gallon per square foot, per hour	1.255	1.045	1.20	1.	1.44	1.92	48.9	1.174
1 cubic foot per square yard per hour	0.869	0.724	0.83	0.69	1.	1.33	33.9	0.813
1 lineal inch, vertical velocity per hour	0.652	0.543	0.62	0.52	0.75	1.	25.4	0.610
1 hundred lineal millimeters, vertical velocity per hour	2.566	2.139	2.46	2.05	2.95	3.94	100.	2.400
1 lineal meter, vertical velocity per 24 hours=1 cubic meter per square meter per 24 hours	1.069	0.891	1.02	0.85	1.23	1.64	41.7	1.

OTHER SOURCES OF WATER SUPPLY.

Pursuant to the directions given by the Board of Advisory Engineers during the December (1900) meeting, the Resident Expert has investigated the character of other sources of supply and reports as follows:

The other sources of supply are:

1.—Rain water.

2.—Deep well water.

3.—Water from streams north of Lake Pontchartrain.

The character of the first source varies greatly from very good and safe to very bad and dangerous, according to locality and mode of collection and storage, as the accompanying results of analyses show.

The water from deep wells contains too much organic matter, color and dissolved mineral matter (alkali) to be considered as a satisfactory source of supply for general use.

The water from the streams north of Lake Pontchartrain is of fair quality; but the streams receive drainage from populated areas, and during the flood season carry objectionable amounts of suspended matter. The water also contains considerable color. The water would therefore require purification. This purification could be effected at a cost of operation somewhat less than that estimated for the purification of the Mississippi River water, per million gallons of water filtered; although the construction cost of the purification plant would be higher. The quality of the filtered water would be excellent, and would be considerably softer than the Mississippi River water, as the accompanying analyses will show.

For the purpose of illustration the following analyses are tabulated below, as follows:

Serial Number.	Description.	Locality.
122	Ponchatoula River water, taken mid-stream, just opposite Ponchatoula Ferry...	Ponchatoula, Tangipahoa Parish, La.
199	Ponchatoula River water, taken mid-stream, just opposite Ponchatoula Ferry...	Ponchatoula. Tangipahoa Parish, La.
215	Old wooden cistern, Girls' High School, New Orleans...	Jackson avenue and Chippewa street.
375	Old wooden cistern, residence, New Orleans....	1004 Aline street.
376	New wooden cistern, residence, New Orleans...	Walnut and Carrollton avenue.
399	New wooden cistern, residence, New Orleans...	6028 Garfield street.
400	Old wooden cistern, office building...	602 Carondelet street.
401	Old wooden cistern, office building...	St. Charles and Canal sts.
402	Old wooden cistern, residence...	718 Dumaine street.
214	Boguefalaya River, sample taken near shore at.	Old Landing.
279	Artesian well, City, car barns...	Napoleon avenue and Tchoupitoulas street.
280	Artesian well, City, Tulane University boiler-house...	St. Charles avenue and Walnut street.
281	Artesian well, City, Consumers' Ice Co...	Magazine and Delord sts.
377	Shallow well (15'), 300 feet from Gulf Coast....	Beauvoir, Miss.
398	Tap water, laboratory, Pasteur filtered Mississippi River water...	602 Carondelet street, New Orleans, La.
180–181	Reservoir water fed from deep wells...	New Iberia, La.

TABLE

Results of Analyses of Samples of Water

(Parts per

Source of Sample.	Tangipahoa River, Ponchatoula.		Cistern, City.	Cistern, City.	Cistern, City.	Cistern, City.
Serial Number	122	199	215	375	376	399
Date of Collection	Mar. 6-01	Apr. 22-01	May 5-01	Aug. 30-01	Aug. 30-01	Dec. 26-01
Date of Examination	" 8-01	" 23-01	" 6-01	Sep. 2-01	Sep. 12-01	" 26-01
Temperature—Degrees C.	15	15	....	....	....	8.5
Odor. Hot	....	....	....	....	....	0
Odor. Cold	1 musty.	1 musty.	0	0	0	0
Turbidity	20	60	0	1	0	0
Color—Hazen's Standard	20	30	5	3	2	5
Oxygen Consumed	4.50	6.60	0.70	2.50	0.90	1.05
Nitrogen as.. Albuminoid Ammonia. Total	.080	.171	.030	.075	.035	.031
Nitrogen as.. Albuminoid Ammonia. Suspended	.055	.100	0	0	.000	.000
Nitrogen as.. Albuminoid Ammonia. Dissolved	.025	.071	.030	.075	.035	.031
Nitrogen as.. Free Ammonia	.015	.017	.005	.020	.002	.020
Nitrogen as.. Nitrites	.001	.000	.000	.000	.000	.000
Nitrogen as.. Nitrates	.100	.060	.090	.120	.180	.080
Chlorin	4.10	2.10	....	4.05	4.50	4.20
Sulphuric Acid—SO_4	....	....	....	....	....	....
Incrusting Constituents	1.0	1.0	....	....	....	......
Alkalinity	8.6	7.8	....	3.8	1.9	....
Residue on Evaporation. Dissolved	41	30	....	23	37	12
Residue on Evaporation. Suspended	27	52	....	1	0	0
Residue on Evaporation. Total	68	82	....	24	37	12
Iron	1.20	3.0	....	.30	.20	.10
Carbon Dioxid (free and half bound)	....	....	....	....	....	....
Dissolved Oxygen	....	....	....	....	....	....

LXIX.

from Various Other Sources of Supply.

Million.)

Cistern, City.	Cistern, City.	Cistern, City.	Boguefalaya River.	Artesian Wells, City.			Shallow Well, Beauvoir.	Pasteur Filtered Miss. River Water.	Artesian Well, New Iberia.
400	401	402	214	279	280	281	377	398	180-181
Dec. 26-01	Dec. 26 01	Dec. 26-01	May 5-01	May 27-01	June 3-01	June 10-01	Sep. 1-01	Dec. 24-01	Apr. 8-01
" 26-01	" 26-01	" 26-01	" 6-01	June 1-01	" 4-01	" 12-01	" 2-01	" 26-01	" 11-01
9.5	10.0	10.0	....	....	....	....	....	9.0	....
0	0	0	....	....	....	....	....	0	....
0	1 veg.	1 mouldy	1 mouldy	1 veg.	1 musty.	1 veg.	0	0	1 veg.
0+	1	1	15	1	2	0	15	0	15
5	10	12	35	440	1400	730	12	10	11
1.20	1.20	1.10	6.8	10.1	14.3	7.80	0.75	1.90	3.0
.033	.063	.070	.181	.131	.181	.133	.022	.065	.090
.000	....	....	.121	....	....	....	....	.000	.035
.033	....	.	.060	.	....	....	....	.065	.055
.048	.030	.490	.007	.006	.029	.025	.010	.036	3.300
.000	.001	.005	.000	.500	.400	.006	.000	.005	.000
.130	.110	.000	.030	.000	.000	1.630	0.120	.060	.000
4.75	4.80	4.50	4.80	479.	....	324	5.6	15.6	10.5
....	....	....	....	4.2	....	10.4	....	....	....
....	....	....	....	0	0	0	....	24.5	0
....	....	....	8.3	420	403	441	4.8	124	430
54	54	35	49	1184	855	1334	....	205	485
....	1	1	17	1	2	0	....	0	15
54	55	36	66	1185	857	1334	84	205	500
.30	.70	.75	.56	2.50	3.20	2.60	2.50	3.0	8.6
....	....	....	....	....	....	....	....	63	520
....	....	....	....	....	....	....	....	9.55	....

TABLE LXX.—*Results of Chemical Analysis of Effluent of Filter No. 1.*

Date.	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved.	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, Dissolved.	Residues on Evaporation, Suspended.	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Dec. 31—1900	......	43	10	4.7	0.115	0.020	0.135	0.024	0.001	0.16	8.5	...	83	160	20	180	11.2	...	...	......	......
Jan. 7—1901	9.9	30	1	2.5	0.071	0.019	0.090	0.015	0.000	0.14	9.9	9	75	149	32	181	8.4	...	...	7.4	......
" 14	8.5	29	8	3.1	0.066	0.014	0.080	0.017	0.000	0.11	9.6	15	90	164	30	194	9.6	49	9	8.1	1,000
" 21	9.5	30	13	3.5	0.040	0.013	0.053	0.007	0.000	0.05	8.5	15	83	141	32	173	7.6	65	28	8.2	......
" 27	11.6	35	14	2.9	0.049	0.008	0.057	0.011	0.001	0.08	8.6	7	83	144	45	189	8.0	85	48	7.1	500
Feb. 4	12.2	35	11	2.3	0.043	0.011	0.054	0.005	0.000	0.14	7.8	13	79	126	24	150	0.6	61	26	8.3	4,400
" 11	10.2	23	13	1.6	0.047	0.013	0.060	0.005	0.000	0.29	7.8	12	69	120	31	151	0.3	59	29	8.4	100
" 18	10.5	20	11	1.4	0.040	0.019	0.059	0.003	0.005	0.11	7.8	13	76	146	34	180	1.0	60	27	7.8	500
" 25	6.8	20	12	2.7	0.052	0.017	0.069	0.006	0.000	0.11	8.6	16	74	144	10	154	1.2	61	29	10.6	600
Mar. 4	11.4	20	11	2.0	0.057	0.034	0.091	0.007	0.001	0.19	9.0	10	70	131	27	158	1.0	80	49	8.9	475
" 18	11.7	13	11	2.5	0.052	0.009	0.061	0.003	0.000	0.10	10.8	9	93	159	20	179	0.96	63	22	11.0	475
" 25	13.7	10	10	2.6	0.050	0.011	0.061	0.001	0.000	0.10	13.8	9	100	182	16	198	0.74	88	44	7.3	325
April 1	15.0	20	12	3.0	0.079	0.024	0.103	0.002	0.001	0.12	7.7	14	72	134	48	182	1.44	46	14	5.7	95
" 8	14.2	25	12	3.5	0.071	0.023	0.094	0.002	0.001	0.12	6.5	16	72	128	38	166	1.16	59	27	7.3	95
" 15	15.7	20	15	3.4	0.078	0.032	0.110	0.009	0.000	0.16	5.7	...	74	126	49	175	......	...	...	......	65
" 22	17.0	20	12	....	0.077	0.046	0.123	0.006	0.001	0.10	......	...	74	......	...	......	......	...	...	......	550
" 29	20.0	20	12	.....	0.065	0.027	0.092	0.005	0.001	0.09	......	...	74	......	...	......	......	...	...	......	220
May 6	21.0	12	11	......	0.072	0.004	0.076	0.003	0.001	0.12	......	...	80	......	...		......	...	...	......	130
" 13	22.0	13	10	......	0.052	0.023	0.075	0.009	0.000	0.09	......	...	76	......	...	......	......	...	...	......	140
" 27	21.3	11	5	......	0.042	0.016	0.058	0.005	0.000	0.06	......	...	80	......	...	......	......	...	...	......	41
June 10	26.3	2	17	......	......	......	0.059	0.004	0.000	0.12	......	...	100	......	...	......	......	...	...	......	55
" 17	27.9	1	13	......	......	......	0.042	0.003	0.000	0.09	......	...	79	......	...	......	......	...	...	......	50
" 24	28.2	1	10	......	......	......	0.042	0.006	0.000	0.07	......	...	73	......	...	......	......	...	...	......	......
July 8	28.8	1	16	......	......	......	0.056	0.003	0.000	0.08	......	...	89	......	...	......	......	...	...	......	31
" 29	28.2	1	15	......	......	......	0.099	0.000	0.000	0.11	......	...	85	......	...	......	......	...	...	......	95

LXXI.—Results of ... of Water No. 2.

Date.	Temperature, Degrees. Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved.	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, Dissolved.	Residues on Evaporation, Suspended.	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Jan. 1—1901	...	0	5	1.1	0.053	0.000	0.053	0.018	0.001	0.21	7.5	...	62	...	...	...	0.00	...	...		850
" 8	9.5	0+	11	0.4	0.042	0.000	0.042	0.017	0.001	0.26	10.1	...	65	...	...	...	0.10	...	...	9.3	2,600
" 15	8.6	10	5	1.2	0.064	0.000	0.064	0.010	0.000	0.13	9.8	24	70	...	..	...	0.25	55	24	8.6	375
" 22	9.6	0	13	2.3	0.045	0.000	0.045	0.009	0.000	0.15	8.8	20	74	...	...	...	0.00	78	45	8.7	325
" 28	11.0	0	5	1.8	0.043	0.000	0.043	0.005	0.000	0.08	9.2	31	67	132	0	132	0.13	61	31	9.0	48
Feb. 5	10.0	0	9	0.9	0.039	0.000	0.039	0.005	0.000	0.11	7.8	29	58	132	0	132	0.05	61	45	9.3	425
" 12	9.5	0	0	1.2	0.026	0.000	0.026	0.001	0.000	0.26	6.9	36	50	119	0	119	0.00	98	77	9.4	22
" 26	7.8	0	4	1.4	0.034	0.000	0.034	0.007	0.000	0.09	8.6	23	54	135	0	135	0.18	90	66	10.6	55
Mar. 5	12.8	0	5	1.7	0.021	0.000	0.021	0.002	0.000	0.12	8.5	31	51	133	0	133	0.17	57	35	10.1	13
" 12	12.9	0	6	1.2	0.025	0.000	0.025	0.000	0.000	0.10	9.1	26	64	132	0	132	0.37	54	26	9.5	12
" 19	14.0	0	9	1.9	0.030	0.000	0.030	0.002	0.000	0.12	11.6	28	91	164	0	164	0.24	88	48	9.4	31
" 26	13.4	0	5	1.8	0.048	0.000	0.048	0.003	0.000	0.12	14.5	15	86	185	0	185	0.15	85	47	8.6	25
April 2	14.6	0	5	1.6	0.033	0.000	0.033	0.000	0.002	0.16	7.5	36	58	144	0	144	0.25	33	8	7.2	8
" 9	14.2	0	0	3.6	0.066	0.000	0.066	0.002	0.000	0.14	6.7	50	44	135	0	135	0.17	50	31	7.1	5
" 30	18.0	0	5	...	0.053	0.000	0.053	0.001	0.000	0.10	...	..	56	...	...		...	...	...	...	18
May 7	20.0	0	2	...	0.051	0.000	0.051	0.005	0.000	0.09	...	...	60	...	...	...	...	...	...		23
" 14	21.0	0	3	...	0.037	0.000	0.037	0.002	0.000	0.10	...	...	52	...	...	...	...	...	...		150
" 21	20.2	0	3	...	0.053	0.000	0.053	0.005	0.000	0.08	...	...	56	...	...	...	...	...	...	...	21
" 28	21.8	0	5	...	0.053	0.000	0.053	0.001	0.000	0.04	...	..	76	...	...	...	...	...	...	...	15
June 4	23.6	0	6	...	0.065	0.000	0.065	0.003	0.000	0.14	...	...	90	...	...	...	...	...	...	...	95
" 11	24.1	0	3	...	0.035	0.000	0.035	0.003	0.000	0.14	...	...	77	...	...	...		...	...	...	30
" 18	26.8	0	3	...	0.042	0.000	0.042	0.003	0.000	0.08	...	...	54	...	...	...	...	...		...	20
" 25	27.2	0	10	...	0.039	0.000	0.039	0.003	0.000	0.08	...	...	71	...	...	...	...	...	..	...	70
July 2	28.2	0	5	...	0.039	0.000	0.039	0.005	0.000	0.08	...	...	69	...	...	...	...	...	...	...	26
" 16	29.5	0	2	...	0.037	0.000	0.037	0.005	0.000	0.08	...	...	61	...	...	...		...	...	...	29
" 23	29.7	0	5	...	0.027	0.000	0.027	0.006	0.002	0.09	...	...	68	...	...	...	...	...	...	...	16
" 30	28.0	0	11	...	0.062	0.000	0.062	0.005	0.000	0.09	...	...	83	...	..	...	...	...	...	...	90
Aug. 6	28.0	0	11	...	0.042	0.000	0.042	0.005	0.001	0.09	...	..	97	...	.	...	...	...	...	...	85
" 13	28.0	0	11	...	0.036	0.000	0.036	0.001	0.000	0.22	...	...	106	...	...	...	...	...	...	...	22

TABLE LXXII.—*Results of Chemical Analysis of Effluent of Filter No. 3.*

Date.	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved.	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, Dissolved.	Residues on Evaporation, Suspended.	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Dec. 26—1900	.....	0	9	1.4	0.071	0.000	0.071	0.006	0.018	0.34	8.0	32	.....	106	0	106	0.00	...	...	.....	950
Jan. 2—1901		0	3	0.7	0.051	0.000	0.051	0.012	0.013	0.20	8.0		59	141	0	141	0.15				300
" 9	9.4	0	5	0.8	0.027	0.000	0.027	0.008	0.000	0.19	10.5	44	55	154	0	154	0.00	...	...	10.0	210
" 17	8.7	0		1.5	0.052	0.000	0.052	0.009	0.012	0.06	8.9	28	77	164	0	164	0.00	50	16	10.3	3
" 23	9.4	0	6	1.4	0.025	0.000	0.025	0.003	0.004	0.09	8.6	28	55	141	0	141	0.80	86	62	10.0	32
" 30	11.6	0	5	1.2	0.038	0.000	0.038	0.016	0.011	0.07	8.8	39	60	140	0	140		72	46	10.2	14
Mar. 6	8.0	0	5	1.2	0.018	0.000	0.018	0.010	0.006	0.16	8.6	35	47	147	0	147	0.27	104	85	11.0	17
" 13	12.7	0	8	1.4	0.046	0.000	0.046	0.008	0.006	0.09	8.5	26	62	129	0	129	0.19	62	35	9.7	50
" 20	11.4	0	3	1.1	0.043	0.000	0.043	0.008	0.011	0.04	11.7	27	87	169	0	169	0.25	74	36	9.9	95
" 27	12.0	0	0	1.0	0.024	0.000	0.024	0.007	0.014	0.14	20.0	46	6[illegible]	174	0	174	0.17	68	41	8.8	50
April 3	12.0	0	2	1.3	0.032	0.000	0.032	0.003	0.003	0.15	7.5	54	46	184	0	134	0.28	40	20	8.5	8
" 10	12.7	0	3	2.8	0.049	0.000	0.049	0.004	0.001	0.12	6.7	46	45	132	0	132	0.15	69	49	8.5	13
May 8	18.0	0	2	......	0.026	0.000	0.026	0.003	0.002	0.08	......	...	39	......	..					......	130
" 15	21.0	0	1	......	0.034	0.000	0.034	0.003	0.002	0.12	......	...	42	......	...	......				......	230
" 22	21.0	0	2	......	0.035	0.000	0.035	0.006	0.000	0.06	......	...	57	......	...	......				......	65
" 29	21.7	1	7		0.069	0.000	0.069	0.001	0.000	0.20	......	...	73	......	...	......				......	900
June 5	23.4	0	5	......	0.059	0.000	0.059	0.031	0.000	0.17	......	...	84	...	...	......					1,200
" 12	24.5	0	1	......	0.026	0.000	0.026	0.007	0.000	0.10		...	61	......	...	......	......	...		......	65
" 19	28.8	0	0	......	0.029	0.000	0.029	0.003	0.000	0.04	......	...	53	......	..	....	......	...			43
" 26	27.2	0	0	......	0.029	0.000	0.029	0.003	0.000	0.08	......	..	58	......	...		......	...		......	100
July 3	28.0	0	8	......	0.039	0.000	0.039	0.003	0.001	0.16	......	...	70	......	...	......	......	...		......	700
" 10	28.9	0	4	......	0.025	0.000	0.025	0.007	0.002	0.07	......	...	61	....	...	......	......	...		..	110
" 17	29.0	0	4	......	0.031	0.000	0.031	0.004	0.002	0.07	......		58	......	...	......	......	...		......	110
" 24	28.9	0	5	......	0.040	0.000	0.040	0.005	0.003	0.07	......	...	63	......	...	...	......	...		......	195
" 31	28.9	0	4	......	0.037	0.000	0.037	0.012	0.002	0.09	......	...	70		...	......	......	...	...	......	800
Aug. 7	29.9	0	7	......	0.034	0.000	0.034	0.008	0.002	0.15	......	...	88	......	...			...	..		150
" 14	29.5	0	6		0.042	0.000	0.042	0.004	0.001	0.08		...	98	......	...		...	...			34

Date.	Temperature, Degrees, Cent.	Silica Turbidity.	Color.	Oxygen Consumed.	Nitrogen as Ammonia, Albuminoid, Dissolved	Nitrogen as Ammonia, Albuminoid, Suspended.	Nitrogen as Ammonia, Albuminoid, Total.	Nitrogen as Ammonia, Free.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Incrusting Constituents.	Alkalinity.	Residues on Evaporation, Dissolved.	Residues on Evaporation, Suspended	Residues on Evaporation, Total.	Iron.	Carbon Dioxide, Free and Half-bound.	Carbon Dioxide, Free.	Dissolved Oxygen.	Bacteria, per Cubic Centimeter.
Dec. 27—1900..	......	0	4	1.0	0.055	0.000	0.055	0.005	0.024	0.17	7.0	40	72	117	0	117	0.00	...	...	......	250
Jan. 3—1901...	... ..	0	2	0.4	0.024	0.000	0.024	0.004	0.006	0.22	7.9	35	45	163	0	163	0.00	...	...	......	375
" 10	11.7	0	3	0.5	0.059	0.000	0.059	0.008	0.012	0.10	10.4	43	53	154	0	154	0.00	...	...	10.3	800
" 17...........	8.2	0	5	0.4	0.028	0.000	0.028	0.007	0.010	0.02	8.9	46	64	149	0	149	0.00	37	9	10.7	3
" 24...........	10.0	0	4	1.0	0.029	0.000	0.029	0.009	0.006	0.10	8.8	23	59	141	0	141	0.00	62	36	10.4	9
" 31.....	9.0	0	6	1.0	0.026	0.000	0.026	0.011	0.013	0.12	8.0	31	64	137	0	137	0.00	69	41	10.5	20
Feb. 7...........	9.8	0	5	1.4	0.028	0.000	0.028	0.005	0.016	0.20	7.6	30	50	129	0	129	0.10	80	58	10.2	55
" 13...........	8.6	0	2	0.8	0.020	0.000	0.020	0.010	0.011	0.12	9.6	46	43	134	0	134	0.14	89	70	9.1	21
" 21	6.9	0	3	1.0	0.045	0.000	0.045	0.014	0.005	0.10	7.3	37	55	145	0	145	0.28	107	83	10.7	25
" 28...........	8.0	0	5	1.1	0.026	0.000	0.026	0.012	0.005	0.16	9.6	31	43	138	0	138	0.18	68	49	11.4	120
Mar. 7...........	9.1	0	5	0.9	0.031	0.000	0.031	0.009	0.005	0.11	8.9	33	55	143	0	143	0.12	89	65	10.8	25
" 15...........	11.7	0	9	1.2	0.031	0.000	0.031	0.021	0.006	0.06	9.5	26	73	137	0	137	0.19	75	43	9.6	28
" 21	11.8	0	5	2.1	0.042	0.000	0.042	0.012	0.014	0.09	13.6	26	93	184	0	184	0.35	83	42	10.1	100
" 28	13.0	0	0	1.3	0.057	0.000	0.057	0.010	0.003	0.15	9.1	62	39	178	0	178	0.27	52	35	8.8	24
April 4	12.8	0	0	1.7	0.036	0.000	0.036	0.002	0.005	0.11	8.0	42	43	135	0	135	0.47	50	31	8.4	15
" 11...........	12.0	0	5	1.5	0.049	0.000	0.049	0.003	0.002	0.12	6.1	44	48	139	0	139	0.17	62	41	8.2	43
" 19...........	16.0	0	0	1.2	0.050	0.000	0.050	0.003	0.003	0.10	......	...	43	128	0	128	......	...	...	......	11
May 9..........	19.0	0	2	......	0.042	0.000	0.042	0.006	0.001	0.09	......	...	52	......	...	......	......	...	...	......	100
" 16...........	20.0	0	0	......	0.024	0.000	0.024	0.003	0.002	0.12	......	...	41	......	...	......	......	...	...	......	110
" 30	22.0	0	0	......	0.068	0.000	0.068	0.002	0.000	0.10	......	...	76	......	...		......	...	...	......	275
June 6...........	24.1	0	5		0.047	0.000	0.047	0.005	0.000	0.14	......	...	79	......	...	......	......	...	...		275
" 13......... ..	24.5	0	1	......	0.033	0.000	0.033	0.003	0.000	0.08	......	...	66	......	...	......	......	...	...	......	325
" 20...........	26.6	0	0	......	0.029	0.000	0.029	0.009	0.000	0.04	......	...	55	......	...	......	......	...	...	......	60
" 27	27.2	0	0	......	0.040	0.000	0.040	0.003	0.001	0.08	......	...	61	......	...	......	......	...	...	......	500
July 4...........	27.2	0	2	......	0.036	0.000	0.036	0.008	0.001	0.07	......	...	63	......	...	......	......	...	...	......	50
"11-12...........	30.0	0	3	......	0.043	0.000	0.043	0.009	0.002	0.05	......	...	61	......	...	......		...	...	......	1,400
" 22...........	29.1	0	5	......	0.044	0.000	0.044	0.005	0.002	0.07	......	...	63	......	...	......	......	...	...	......	100
" 25	28.7	0	5	......	0.038	0.000	0.038	0.005	0.002	0.05	......	...	61	......	...	......	......	...	...	......	750
Aug. 1	29.0	0	5	......	0.061	0.000	0.061	0.006	0.001	0.11	......	...	82	......	...	......	......	...	...	......	750
" 8......	29.9	0	6	......	0.031	0.000	0.031	0.012	0.002	0.31	......	...	85	......	...	......	......	...	...	......	600
" 15...........	28.0	0	10	...	0.043	0.000	0.043	0.005	0.001	0.13	......	...	102	......	...	......	......	...	...	......	200

TABLE LXXIV.

Character of the Mississippi River Water.—Maximum, Minimum and Average Results for Year Ending August 31, 1902.

			Maximum.	Minimum.	Average.
River Gauge—Feet			18.85	.00	4.95
Temperature—Degrees C.			31.0	8.0	18.3
Odor			3 E.	0	2 E.
Turbidity—Silica Standard			2800	40	740
Color—Hazen's Standard			17	8	11
Oxygen Consumed			23.8	2.4	10.6
Nitrogen as	Albuminoid Ammonia.	Total	.800	0.080	.351
		Suspended	.720	0.022	.270
		Dissolved	142	.019	.081
	Free Ammonia		.077	.000	.016
	Nitrites		.028	.000	.005
	Nitrates		1.81	0.10	0.63
Chlorine			51.0	8.0	16.1
Incrusting Constituents			79	11	39.5
Alkalinity			160	58	90
Residue on Evaporation.	Total		1785	205	835
	Suspended		1545	65	650
	Dissolved		275	115	185
Iron			58 0	4.0	25.1

New Orleans, La., November 6, 1902.

MR. GEO. G. EARL,

General Superintendent, Sewerage and Water Board, New Orleans

DEAR SIR:—In compliance with your request I present herewitl a report of the investigations made last autumn, to ascertain if ther were any trace of salt from the gulf in the Mississippi River opposit the city; and also of the bacteriological tests made this past summe on the American Filter at Audubon Park.

As the gulf water enters the river in sufficient quantities to mak its presence felt at New Orleans only at very low stages of the rivei observations were confined to that time when the river was lowest.

Daily observations were made on the amount of chlorine in san ples of the river water taken about three feet below the surfac opposite Lafayette Street, from November 21st to December 21st, an below is given a tabulation of the same, together with the correspondin stage of the river.

TABLE LXXV.

Date, 1901.		Chlorine Found. Parts per Million.	Stage of River, Feet.	
			Carrollton Gauge.	Above Mean Gulf Level.
Nov.	21	14.1	.30	—.05
"	22	14.1	.45	+.10
"	23	15.5	.45	+.10
"	25	15.0	.30	—.05
"	26	15.5	.30	—.05
"	27	14 6	.25	—.10
"	28	15.1	.40	+.05
"	29	15.3	.35	—.00
"	30	15.5	.25	—.10
Dec.	2	14.2	.40	+.05
"	3	15.0	.40	+.05
"	4	15.9	.25	—.10
"	5	16.4	.20	—.15
"	6	16.4	.25	—.10
"	7	19.3	.30	—.05
"	9	18.8	.50	+.15
"	10	19.0	.35	—.00
"	11	17.8	.30	— 05
"	12	16.6	.50	+.15
"	13	16.3	.80	+.45
"	14	16.1	.50	+.15
"	16	15.8	.55	+.20
"	17	18.7	.30	—.05
"	18	18.0	00	—.35
"	19	18.5	.00	—.35
"	20	17.3	.00	—.35
"	21	17.5	.00	—.35
"	22-28	13.3	.....	....
" 30 to Jan. 4		12.0	.....	....

On November 21st a series of samples was taken at midstream, ›osite Canal Street, at different depths, and analyzed for chlorine, h the following results:

TABLE LXXVI.

No. of Sample.	Depth below Surface. Feet.	Chlorine. Parts per Million.
1	0	14.1
2	25	14.0
3	50	14.8
4	75	14.8
5	100	14.4
6	125	14.5

The turbidity of the river at the surface was 60 parts per million, ile at a depth of 100 feet it was but 30 parts per million.

On December 11th another series was taken at midstream a little above Canal Street. Analysis of the samples showed chlorine contents as follows:

TABLE LXXVII.

No. of Sample.	Depth below Surface. Feet.	Chlorine. Parts per Million.
1	0	17.8
2	25	16.7
3	50	18.0
4	75	17.4
5	100	17.8

The turbidity of the river at the surface was 80 parts per million, and about 50 parts per million at a depth of 75 feet.

An inspection of Table LXXV shows that while there is an increase in the amount of chlorine in the daily samples taken near the surface of the river, during the period of low water, that increase is very slight and can be detected only by the delicate methods of the laboratory, and is far from being appreciable to the taste. The minimum amount of chlorine that can be detected by the sense of taste of the average person being about 200 parts per million.

The variation in the amount of chlorine at different depths, as shown by Tables LXXVI and LXXVII is practically nothing, and within the limits of error of sampling and analysis.

The results of this investigation show that at no time during the low water period during the Fall of 1901 did Gulf water enter the Mississippi River in sufficient quantity to make its presence felt at New Orleans.

During the Summer and Fall of 1902 the regular weekly analyses of the river water showed no material increase in the chlorine contents of the water.

In regard to the bacterial tests made at Audubon Park during the Summer of 1902, I beg to submit the following:

The period of tests extended from July 15th to September 1st. It had been our aim to get results to show the effect of ageing of the sand layer which had been in the filter for about a year. But in this we were disappointed as the park employees had taken out the old sand and replaced it with new sand about a month before we started our work. This sand was similar to the No. 3 sand used in these filters during the investigation under Mr. Weston, having an effective size of about 0.340 millimeters.

In carrying out our tests, while close watch was kept of the operation of the plant, no attempt was made to regulate the methods of operation, or rate of filtration; the men in charge being governed only by the quantity of water required for use.

general, the plant was operated daily from 7 a. m. to 5 p. m., te of about 175,000,000 gallons per acre per 24 hours; or for er used 37 gallons per minute, this being about 50% greater hat is considered the normal rate for this type of filter.

ıually the filter was washed twice a day, according to the regular l.

ıere were a number of days during the test when the filter was ıning, either because of repairs to the plant or because the water t needed.

ıe average period of plain subsidence was about 10 hours, and :rage period of coagulation was about 6 hours.

ıe amount of coagulant used was about 2.5 grains per gallon of iltered.

ıe conditions under which the test was made were far from ideal aining the best results, as the irregular operation of the filter, ɔwing it to stand over night unwashed and filled with coagulated fostered bacterial growths in the sand layer and under-drains undoubtedly caused relatively higher numbers of bacteria in the : than would have obtained had the filter been operated con- ıly, and not allowed to pass turbid water, as it sometimes did.

:vertheless, the results obtained were of considerable value, and whole, were satisfactory from a sanitary standpoint. While the 's in the effluent averaged somewhat above 100 per cubic centi- the German standard, the bacterial efficiency was very good.

ıe river was more turbid and contained more bacteria during the .n at any time during the investigation of 1900 and 1901. Daily s were taken, except on days when the filter was out of service.

low is given a table showing the maximum, minimum and aver- mber of bacteria in the water at each stage of its treatment, :r with the maximum, minimum and average efficiencies of the

TABLE LXXVIII.

:.	Number of Bacteria per Cubic Centimeter.			Bacterial Efficiency of Filter.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
......	16,000	2,300	8,000	99.4	96.0	98.2
......	12,000	1,100	4,500	. ....	......	. ....
......	8,000	300	1,800	......	......	......
......	300	21	110	......	.....	......

:.—S. B. = Subsiding Basin Effluent.
C. B. = Coagulating Basin Effluent.

Respectfully submitted,

JOHN L. PORTER,

Chemist.

CHAPTER IX.

SUMMARY AND REVIEW OF THE WATER PURIFICATION QUESTION BY MESSRS. HERING & FULLER.

NEW YORK, July 10, 1902.

George G. Earl, Esq., General Superintendent, Sewerage and Water Board, 602 Carondelet Street, New Orleans, La.:

DEAR SIR:—Pursuant to your request of June 24, 1902, for a brief statement covering the more salient and practical features of the investigations recently conducted at the water purification station at Audubon Park, we report as follows:

These investigations were deemed necessary by the Board of Advisory Engineers at their first meeting, held in June, 1900, to aid in deciding upon the source and also the manner of treating the water to be supplied to New Orleans; and the purification station at Audubon Park was built and operated along the general lines discussed at that meeting. Each of us has followed carefully the leading results accomplished at the station under your general direction, and the immediate supervision of Mr. Robert S. Weston, the expert in charge. One of us, Mr. Fuller, has, on several occasions, thoroughly reviewed matters upon the ground, and has currently followed the course of the work, as shown by Mr. Weston's bi-weekly reports, and by frequent correspondence, in as much detail as was possible from this distance. Each of us has studied carefully the final report of Mr. Weston, dated January 15, 1902, and we consider that he has conducted the tests judiciously, and that he has reported their conditions and results comprehensively and correctly.

In view of the detailed report made by Mr. Weston, which we understand is now about to be printed, it is, of course, unnecessary for us here to touch upon many points which will be of importance, not only in the construction, but in the operation of the projected purification works. The more salient features, however, may, in our judgment, be tersely summarized as follows:

Regarding the character of the Mississippi River water at New Orleans, the numerous detailed analyses, both chemical and biological, show that the water, apart from the sediment which it contains, is well adapted for domestic and commercial uses. As to sewage pollu-

n, the evidence shows decisively that this factor is of practically no nificance, owing to the enormous dilution which this river has orded to the sewage discharged into it many hundred miles above w Orleans. In its raw condition the river water at this point is ite safe hygienically; and it can be stated without qualification that r many years to come, any process or treatment which will adequately rify it will also purify it satisfactorily.

In connection with the design of an economical and efficient system purification works, the records obtained of the amount and character the sediment contained in the river water during the various stages d seasons are of much importance. Comparative studies were made so of the current records and of the valuable data accumulated sys-matically for many years by the Mississippi River Commission, in ch a manner that the latter have been of considerable assistance in ese investigations. Taking all the information together, we are of e opinion at the present time that there is probably no place where ore comprehensive knowledge exists as to the character of a turbid ater than at New Orleans.

Concerning methods of purification and of clarification, it is the ustom in some places, as you know, especially in Europe and in the Northeastern States, to accomplish this by allowing the water to slowly ilter through beds of sand, called by some, English filters. The rate t which the water passes through the beds ordinarily ranges from bout 3 to 6 vertical inches per hour, or from about 2 to 4 million gal-ons per acre per 24 hours. With waters which are not very turbid, ven when they are much polluted with sewage, very satisfactory re-ults have been obtained both as to the appearance of the filtered water nd its hygienic character.

At New Orleans the passage of the raw river water through such eds of sand would be impracticable, because the cost of scraping off he mud from the surface of the sand layers would be prohibitive, to ay nothing of the fact that for many months at a time the filtered ater would itself remain decidedly muddy.

There is another method of filtration which during the past 20 ears has been developed in this country, and which has been much racticed in connection with the sugar industry in the general vicinity f New Orleans. By this process the water is coagulated, or curdled, y means of a suitable chemical, so that the particles of silt and clay e collected into relatively large masses, and then the foreign sub-ances are strained out by filtering at a very rapid rate through beds sand. This process, now well known, is variously called the echanical, rapid, or American type of filtration. On a large scale it

would not be practicable to clarify and purify the raw Mississippi River water at New Orleans by this means alone, on account of the cost both for installation and maintenance.

For many years attention has been given at places in this country and abroad to the partial clarification of turbid river water by means of subsidence (sedimentation) in relatively large basins. As a first step in the preliminary treatment of turbid waters, to prepare them for filtration, it is of great assistance, and its applicability has been carefully studied at the station at Audubon Park.

The evidence as to the limitations of plain subsidence as a preparatory treatment to filtration, however, shows that, owing to the amount and fineness of the clay in the Mississippi River water, this process is by itself entirely inadequate under the local conditions. In fact, were the entire amount of money available for the construction of a complete new system of water works in New Orleans available exclusively for the construction of subsidence or settling basins, they would not be capable regularly of affording an adequate preparation so that the water could be properly filtered at the slow rate which has for many years given satisfactory results in Europe.

In the Mississippi Valley the situation with reference to turbidity of the water of the principal streams is quite unique, and it is distinctly unlike, and more difficult than, almost every instance throughout the world from which accurate information is available with regard to the purification and clarification of water on a large scale.

As set forth in the first report of the Board of Advisory Engineers, the preliminary treatment of the local water is a distinct problem in itself. With most turbid waters the importance of this is now more clearly and generally recognized than was the case even at the time when these investigations were started. It is cheaper and better to do the great majority of the work before the water reaches the filters, thus allowing the latter to be operated on a uniform and systematic basis, at higher rates of filtration, and at a decidedly reduced cost, both as to fixed charges and expenses of operation, comparatively speaking.

Especial attention was given at the water purification station at Audubon Park to determine the most practicable limits to which the water should be clarified before applying it to each of the two types of filters above stated, and upon this point the tests gave much information of practical value.

With a water such as that of the Mississippi River at New Orleans it is necessary in the preparatory treatment to make use of coagulation, or some process by which the almost infinite number of sub-microscopic clay particles can be eliminated in an economical manner. During these

restigations coagulation has been obtained by means of sulphate of .mina, a process which in its general features has been applied for .ny centuries in a small way, and with which many of your citizens : thoroughly familiar. By means of such a treatment and subsequent osidence it is possible to effect almost complete clarification of the ter. It is not judicious, however, to make this process, on a large le, to do the entire work of clarification, because a considerable rtion of coarser sediment can first be more cheaply and successfully noved by means of plain subsidence, and the last traces of clay parles can be removed more advantageously and completely by means filtration than by prolonged settling.

With regard to the practicability of applying a coagulation process the Mississippi River water, it can be stated without qualification it the composition of the water is such that this can be done readily d safely.

Among the most important lessons learned from the investigations Audubon Park is that showing the economical and most practical vision of work under local conditions between plain subsidence and agulation, followed by supplementary subsidence. Obviously, it is t desirable to build a large reservoir to settle the water beyond the iit where clarification can be more economically accomplished by eans of the coagulating treatment, especially under the existing ysical and financial conditions at New Orleans. We have examined e evidence submitted by Mr. Weston, and concur in his conclusion at for plain subsidence the reservoirs (uncovered) need not be of a pacity to hold more than about 12 hours' supply.

Regarding the second step in the purification works, namely, the plication of a coagulant to the partially clarified water coming from ttling basins, and its subsequent sedimentation, the evidence obtained Mr. Weston is of much assistance. It shows not only a schedule dicating the required amount of coagulant for waters of different grees of turbidity, but also shows the effect upon filters of each type, further sedimentation for different periods and under different nditions.

It is properly concluded that after the local water has been settled about 12 hours, it should be coagulated and settled for an additional riod of 24 hours (total period, 36 hours) in order to prepare it propy for filtration at a slow rate through sand beds (English filters), d for an additional period of 12 hours (total period, 24 hours), in ler to prepare it for filters of the mechanical or American type. The ison why more complete settling is required in the case of the glish filters, is that the coagulated masses with this type of filters uld accumulate at the surface of the sand layer and quickly choke

the filter, whereas the velocity in the other type of filter is so great that this would not occur, as the entire bed of sand takes part in the filtration rather than the surface and upper portion of the layer.

On those occasions when the water was fairly clear as it came from the river it would, of course, be feasible to by-pass a portion of the basins and use only such as needed. The coagulating basins need not be covered, but their sides should be shaded to prevent vegetable growth on the walls.

As to the relative merits, both as to cost and efficiency, of the two types of filtration, coupled with their respective preparatory treatments in as advantageous a manner as practicable, Mr. Weston shows that both are entitled to practically the same rating as far as quality of filtered water is concerned, and that the American or mechanical filter is clearly the cheaper in total cost, and for its installation there would be a saving of about $500,000.

This conclusion, of the same general purport as that reached as the results of the investigations made at Louisville and at Cincinnati with the similar but less turbid Ohio River water, is unquestionably logical and sound, and its adoption will afford the best and cheapest means for the City of New Orleans to secure a first-class public water supply. Not only is this method of filtration of the Mississippi River water better than that afforded by any other treatment which has now been investigated for such turbid water, but it is also superior to any project of securing a suitable supply from sources other than the Mississippi.

As to the details of filter construction, several important features were learned with reference to the sand layer and to the air method of stirring the sand during washing. This type of filter, which is no longer controlled by patents, can be constructed in a simple and durable manner, as is the case with some plants already projected and under construction. After having suitably prepared the local water in reservoirs for filtration, the filters proper will not require any features of a hazardous or experimental nature.

Regarding the cost of works for clarifying and purifying the river water in a first-class manner by this method, we consider that the general estimates used by Mr. Weston for the sake of comparison, while they are approximate only and made without complete drawings, are reasonable. For a plant of a rated capacity for each of its parts of 40 million gallons daily, these estimates indicate that the initial outlay will amount to about $700,000, exclusive of the pumping stations. In building these works it will probably be found advantageous to make

some of the parts larger and others smaller than this capacity, and accordingly the total cost may be somewhat increased or decreased with reference to the sum above stated.

Combining both the capital charges on the original outlay on the above basis, and all operating expenses, including pumping to the purification works, we consider that it is perfectly feasible uniformly to deliver first-class filtered water to the main pumping station at about 1½c. per thousand gallons, and into the piping system of the new works, at a total cost of less than 2½c. per thousand gallons.

In concluding this brief review of our opinion concerning the important matter of water purification, we can not refrain from calling to your attention the point emphasized by Mr. Weston, namely, that these purification works, to be operated economically, as well as to produce a high grade of filtered water, must be in the hands of well trained and competent attendants.

Very truly yours,

RUDOLPH HERING,

GEORGE W. FULLER,

Consulting Engineers.

CHAPTER X.

The Proposed Sewerage System.

Mr. Geo. G. Earl, General Superintendent, Sewerage and Water Board:

Dear Sir:—In compliance with your request for a brief description of the plans adopted for the Sewerage of New Orleans, I beg to submit the following:

CAUSES WHICH HAVE PREVENTED THE SEWERING OF NEW ORLEANS.

It is now over 50 years since Dr. Barton urged upon the City of New Orleans the construction of an underground Sewerage System. During these 50 years the number of people who believed Sewerage either possible or desirable for the City of New Orleans has gradually increased. Ultra conservatism and an exaggerated conception of the difficulties imposed by local conditions upon the construction and operation of a sewerage system have in times past been the strong factors preventing a vote for sewerage construction, and in reconciling the people of New Orleans with the somewhat primitive methods of sewage disposal which have prevailed in various forms since the founding of the city.

EXISTING CONDITIONS AS TO SEWERAGE.

The existing methods of sewage disposal may be briefly described as follows:

A few of the larger business houses, hotels and public buildings own or are connected with private force mains, through which their sewage is forced or pumped into the river by the nearest route; some of the better class of residences are fitted with modern plumbing, discharging into cesspools which, in many cases, leach into the surrounding soil or overflow, illegally, into the gutters. The great bulk, however, of the 56,000 premises are served by closets in the rear, the contents of which are removed at intervals by one of the numerous "Sanitary Excavating Companies."

FUNDS AVAILABLE FOR PRESENT CONSTRUCTION LIMITED.

The law under which the Sewerage and Water Board is organized required the service of the whole populated area of the city with Sewerage and Waterworks Systems.

The amount of money available for the construction of these sys-
s is definitely limited, and the problem of designing systems that
ıld satisfy this present requirement, remain within the limits of
sent possible expenditure, and still form economical and satisfac-
parts of ultimate systems, had to be solved.

AREA TO BE SEWERED.

The area for present construction embraces the territory shown in
te on Plate ~~XIII~~ XXIV, covering about 13 square miles. The hatched
ı constitutes that portion now unbuilt, but into which the city will
and as its population increases, and into which extensions will
e to be made to meet this growth. The two areas combined extend
n the upper to the lower city limits, and from the Mississippi River
k to Metairie and Gentilly Ridge, and cover about 23 square miles.

METHOD OF DISPOSAL OF SEWAGE.

For New Orleans, fortunately, the method of sewage disposal is
a question requiring great consideration. The Mississippi River,
rying from 200,000 to nearly 1,500,000 cubic feet per second of silt-
en water, is continually flowing past the city on its way to the
lf, a hundred miles away.

This vast volume of water will afford immediate dilution to the
le stream of sewage which New Orleans has to discharge, and will
effectually disperse it that once properly discharged into the river
vill be lost to the discovery of any human sense. No city exists
ow New Orleans to object to such method of disposal, and none
ve which does not itself make a similar use of this same river.

It only remains, therefore, to choose such points and methods of
let into the river as will be free from local objection. An eddy
r the French Market, and a return current on the New Orleans side
he river extending far up stream from this eddy, are the important
tors, locating the highest safe point of outlet; anywhere below this
y, and well out into the current of the river, the discharge of
age can have no possible objection. A large number of float
ervations, taken along the lower city front, confirm this view, and
result of the study thus made was the choice of the locality at the
t of Spain street as being safely below all influence of the eddy
ve named, and in every way a suitable outlet for sewage. At this,
at another outlet below this point, several submerged pipes will
ver and disperse the sewage well out into the current of the river
some 25 or 30 feet below the surface at low water.

All floating matter will have been screened from the sewage
re it is discharged into the river, and there will, therefore, be

nothing to lodge on the shore; while such suspended matter as is contained will remain suspended and be effectually carried away by the river current.

Having chosen the points of outfall it remained to devise the most efficient and economical method of bringing the sewage from the various parts of the city to these points.

Considerations of the topography of the city and the underground conditions to be met, as well as the quantity of sewage to be dealt with, necessarily determined the best method of sewage collection and dictated depths, grades and details generally to be adopted. An outline of these various questions follow:

CHARACTER OF GROUND.

As the chief obstacle which has doubtless for so many years stood in the way of this desirable sanitary improvement, and upon which there exists an almost universal misapprehension, it is proper that the nature of the ground upon which New Orleans is built should first receive brief attention.

The whole area about New Orleans is alluvial; deposited by the Mississippi River through many ages, and formed from the contributions of a continent.

It consists of clay, sand and peat of many kinds, and in various combinations. While certain classes of material, such as gray sand and blue clay, are, more or less, generally distributed over the entire area, yet the deposits are rather in the form of pockets than well-defined and extended layers or strata.

The clays are of several varieties: blue, gray, white, yellow, black and green having been penetrated by the 92 borings which have been taken. The blue clay is by far the most common; being found over almost the entire area at varying depths and in numerous deposits. The four first mentioned are generally quite stiff, and when properly worked will give a fairly firm and satisfactory foundation for underground structures. The green and black are rare and very soft, failing to afford a proper foundation for any structure, or even to sustain a considerable weight on the surface without disarrangement and upheaval of the contiguous territory.

The sands also are of several varieties; from fine to coarse, and in color—gray, white and yellow. In one case a green sand, which eventually turned white upon exposure, was removed from the drill. The gray sand is most extensive, both in thickness and number of strata, and in general distribution. It is usually found nearer the surface than the other sands, and the upper stratum varies in depth

from eight feet to sixteen feet. The yellow sand is not so much in evidence, being usually found in combination with clay. The white coarse sand is found at greater depths, and contains considerable quantities of shells.

The peat and stumps afford evidence of the existence, at some period, of a cypress swamp throughout this area. The stump layer lies at about the same level; that is, in a horizontal plane, so that as the higher portions of the city are reached its depth below the surface becomes greater. The peaty stratum varies from a few inches to several feet in thickness, and is composed of stumps, roots and a fibrous vegetable matter known locally as "coffee grounds". This latter sometimes exists in large quantities.

The top four or five feet is usually a blue clay, quite compact, or clay mixed with yellow sand somewhat tending to crumble, but both affording a good foundation. Below this is found clay, sand and peat, according to locality.

The three borings shown in Plate XIV will illustrate the varied character of the soil. The first boring is on the site of the water purification station, the second at Pumping Station "A," and the third at Pumping Station "B."

Popular belief throughout the country credits New Orleans with resting upon a soil which is so saturated as to be practically an underground lake. This belief, however, is far from correct. The rate of flow of ground water, or seepage, into an open trench is very slow, though continuous. Excavations regardless of depth are frequently made without any pumping, but will often gradually fill with water if allowed to stand.

Neither the clays nor the peat part readily with their water, and the sand yields but little more. In the latter, however, springs or "boils" in the trench bottom occasionally appear, which contribute a considerable flow and are quite annoying.

The water table, i. e., the point to which ground water will eventually rise in a trench, usually lies at a depth of from 2.5 to 3.5 feet below the surface, though cases are not rare where excavations have been carried to a depth of 12 feet with absolutely no water in the trench, these excavations being either in blue clay or "coffee grounds."

Actual construction in this soil removes much of the misapprehension as to the difficulties to be encountered. Excavations to considerable depth can be made with as much safety and with but little more difficulty than in other soils. Deep excavations, unless made with care and intelligence, may result in subsidence of the adjacent soil and damage to the structures thereon. The fact that large excavations

have been made to a depth of 30 feet with ease and safety should, however, remove all doubts as to the practicability of such excavations as are required for sewerage construction.

POPULATION.

As the Government Census of 1900 had not yet been taken at the time the preparation of plans was begun, it became necessary to seek other sources of information to ascertain the present population to be served by the proposed work.

A count of all the premises within the built up area was taken from a set of insurance maps, supplemented by a count on the ground in those portions of the city not covered by these maps.

Through these sources the total number of premises within the area to be sewered at once was found to be 56,423. Assigning five persons to each gave an existing population in this area of 282,115. The Government Census, taken the following month and published some time thereafter, gave a total population of 287,104. This census, however, covered the entire parish, including Milneburg, West End, Spanish, Fort and the scattered premises outside of the built up area, and these would, to a large extent, cover the 5,000 excess over the above stated estimate of population. This estimate of population of 282,115 gave an average of 31.9 persons to each acre within the inhabitated portions of the city, varying from 8.9 per acre in sparsely built sections to 58.3 per acre in the older portion of the city immediately below Canal Street. Taking the number of premises in each ward, by actual count, it was found that the average number of persons to each premise varies from 3.96 in the Fourth Ward to 6.67 in the Fifteenth Ward. The greatest density of population in each ward over a limited area was found by taking the average number of persons per premise and the number of premises in the area, and varied from 28.8 per acre in the Sixteenth Ward to 84.1 per acre in the Ninth Ward.

More important, however, than the present population was the probable future population, not only in the territory which is to be sewered at once, but in all that territory into which the city will expand in the next fifty years, and which must be provided for in the plans under consideration.

The city was divided into a number of areas, with reference to the probable density of the future population. A density per acre was assigned to each area, varying from 50 in the residential sections to 115 in the central part of the city, giving on this basis an ultimate population of 856,000 within the area covered by the plans drawn, which population a 30 per cent increase per decade would reach in 1942.

While the greatest density assigned to any area is 115 per acre, is number is not to be understood as the maximum population to be und within certain restricted districts but as the average of the hole area within the designated limits; the sewers in the congested stricts being of course designed to serve each particular locality.

AMOUNT OF SEWAGE.

In estimating the amount of sewage to be provided for it was ecessary to make provision for both house drainage and ground vater. The meager available sources of information as to water con-umption could scarcely be considered as a reliable index to a per capita supply, as the existing works numbers among its subscribers a disproportionate number of industrial or other large consumers, as compared to the private or small consumers, and the amount per capita, therefore, is correspondingly increased and incorrect as a basis for estimating the consumption of the entire city.

It was decided to assume that the maximum sewage run off for areas less than 200 acres would be at the rate of 160 gallons per capita in 24 hours. The ground water flow was estimated at one-third of the annual rainfall, amounting to 1,000,000 gallons per square mile in 24 hours. In the calculations used, however, .003 cubic feet per second per acre has been assumed for this quantity, which is equivalent to 1,250,000 gallons per square mile in 24 hours, and it is probable that this latter figure will be reached during continued wet spells, so long as imperfect pavements and surface drainage in parts of the city allow of a large amount of absorption of rainfall.

Ground water flow is usually a most uncertain quantity to determine; practically no comparative information being available. It was most fortunate, therefore, that the opportunity existed to gauge within reasonable limits this factor, which must contribute such a large proportion of the flow.

The sewers constructed by the New Orleans Sewerage Company in 1895 afforded the means for determining this factor. With the permission of the Sewer Company these sewers, both main and pipe, were pumped out, and the amount of seepage through them was measured by pumping same through a three-inch Worthington meter. The examination in each case extended over a period of three weeks, and, therefore, afforded ample opportunity to reach practically correct results. The result was very gratifying in all respects; the flow actually obtained being extremely close to that estimated.

As the area increases there is a natural tendency to a more uniform flow of sewage, because from sections contiguous to the point of final disposal the maximum flow in trunk sewers will have been discharged

before that from the more remote portions of the system reaches this part of them. It was decided, therefore, that for areas of 200 acres or less, the sewers should be designed to handle the aggregate maximum rate of run off, namely, 160 gallons per capita, and 1,250,000 gallons of ground water per square mile in twenty-four hours, and that for areas of 2,000 acres or over the sewers would be proportioned for a run off at the rate of 100 gallons per capita in twenty-four hours, this amount including ground water. Between these two limits, *i. e.*, 160 gallons per capita, plus ground water for 200 acres and 100 gallons per capita for 2,000 acres, the rate of run off was assumed as inversely proportional to the area drained. The sewers were designed to run one-half full for sizes up to 18 inches and seven-tenths full for all larger sizes.

This proportioning of the larger sewers will certainly serve for many years to come, and will guarantee effective depths and velocities for scouring action in the early life of the system. It permits the design of deep low grade sewers to act as collectors in the territory through which they pass, and meets present needs with a minimum of cost and a maximum of efficiency. If eventually any of the trunk sewers are overcharged high level relief lines from such overcharged areas can be very cheaply constructed, substantially as indicated on Plate XIII.

TOPOGRAPHY.

The ground at New Orleans has been built up by the deposits of the Mississippi River; and, following the law of all alluvial formations, the land adjacent to the river is highest, falling away more or less rapidly at right angles to the river.

The highest elevation anywhere is about 37 C. D., or 16 feet above mean Gulf level, and the lowest area of the city is about 10,000 feet back from the river, being at elevation 20 C. D., or one foot below mean Gulf level. There are many places in the city much lower, in some cases dropping to elevation 17 C. D., but these do not affect any considerable area. At a distance of from 18,000 to 25,000 feet back from the river there exists a ridge, rising to an elevation of 26 C. D., known as Metairie Ridge uptown, and Gentilly Ridge downtown. The formation of this ridge is due to the one time existing bayous, Metairie and Sauvage. The territory between this ridge and Lake Pontchartrain is practically tidal swamp. While the area between the ridge and the point where elevation 21 is first reached can be said to be flat, there exists a slight elevation here, or a depression there, which, while apparently inconsiderable in themselves, yet are of great value in any design where every advantage must be taken of the slightest natural slope to arrange an economical and effective plan.

The effect of the topography upon the growth of the city can be derstood by reference to Plate XIII, showing how the city has develed along the higher ground and parallel with the river during the rlier days when drainage was most imperfect, and the only immu:y from several days' submergence after a hard rain, or a long rainy ell, was upon the higher ground. As the drainage improved the y began to extend lakeward. As a result of this direction of owth the city extends along the river a distance of some 12 miles; iile for the greater part of this length its depth is not more than om three-quarters to one and one-half miles.

DEPTH OF SEWERS.

Under the existing conditions the depth of the sewers, both minium and maximum, is of the utmost importance in determining proper and economical design.

The minimum depths must be sufficient to enable house connecons to be properly made, to avoid conflict with obstructions in the rm of other underground structures which have been laid without ly well-defined plan, either as to grades or alignment, and to permit the construction of flush tanks of fair capacity at all dead ends.

The lateral sewers constitute about 87 per cent of the total mileage; nd the maximum depth, therefore, of such lateral sewers governs the verage excavation for the whole system. The character of the round is such as to render deep excavation both undesirable and xpensive. Too shallow a maximum depth on laterals requires an icreased number of flush tanks and an increased annual cost for their peration.

After a thorough consideration of this question a minimum depth five feet and a maximum depth of nine feet for laterals, and a aximum depth of sixteen feet for sub-mains was adopted. These miting depths, however, were not applied to main sewers, economy id efficiency of both construction and operation being secured y an increased depth and a decreased number of pumping lifts. he maximum depth of any main sewer is about 24 feet.

GRADE AND VELOCITIES.

When the topography of much of the area to be sewered is such iat grade can be secured only by artificial means; that is, by constantly icreasing depth or by frequent repumpings, the question of the grade be employed must be carefully considered, not only because of its earing upon the method of collection and alignment, but also with ference to the cost of the work. It is evident that where each foot fall in the sewer means a corresponding increase in its depth, a

FLUSHING.

Recognizing the importance and necessity of flushing provision has been made to flush every block of sewer. For daily flushing reliance is placed upon automatic flush tanks, located at the head of each sewer, and discharging about 300 gallons once in each 24 hours. In addition to this, such hand flushing as may be necessary to keep the system in good order will be accomplished, first, by introducing into each flush tank, and at intervals into manholes along the laterals, a 2-inch pipe, which will be connected directly with the water main and which can be opened full and allowed to run as long as desired. In the manholes on the larger pipe, at intervals, flushing gates will be built which, when closed, will retain the sewage until a sufficient amount has collected to form an effective flush, when it will be released. In the main sewer, also, flushing gates will be built at suitable intervals, and a connection will also be made with the navigation canal from which an abundance of water for flushing can be drawn at will.

EXTENSIONS.

The Sewerage and Water Board enters upon the prosecution of the great works under its direction with its funds limited; first to the amount received from the sale of bonds, and second, to any surplus that may remain after the payment of interest charges on said bonds. As the construction of that portion of the system which serves the present populated area will draw heavily upon, if not entirely consume, the amount realized from the bonds, together with the tax that will accumulate during the period of construction before all bonds have been issued, it was clearly the part of wisdom to so lay the foundation of the system that those portions needed for immediate construction would serve the entire area when built up. By so doing, the minor extensions, rendered necessary by the expansion of the city, could be made with the small surplus from the tax each year available to the Board. This could not be done if any extent of large and deep mains were left to be constructed as those extensions were required. Thus, when the now unbuilt portions of the city lying back of Claiborne Street have need for these facilities, a small pumping station can lift the sewage from each district into the mains to be now constructed, which will handle this flow for years to come; and when, if ever, the increase in the amount of sewage threatens to overcharge these mains, a high gravity main of proper size can be constructed at a moderate cost to deliver the sewage to the main central pumping station.

SEWAGE COLLECTION.

A careful study of the problem of collection early indicated the undesirability of any attempt to deliver the sewage to the main collecting sewer by straight lines running from the river to the rear, or from the initial point to the main. Without collecting enough sewage to increase the size, and thus lessen the required slope, such sewers would soon attain depths that would render them very expensive to construct, and would call for the location of the main collecting sewer very near the river front, leaving large areas in the rear in flat territory where collection to local wells and pumping would be required. In addition to the expense due to extra average depth of lateral sewers the number of dead ends requiring flush tanks would also be greatly increased.

After exhaustive study it became clearly evident that the proper solution consisted in a rapid concentration of the flow of the laterals into larger sewers or sub-mains. In the section lying along the river this system was greatly facilitated by the fact that the natural slope of the ground was greater than the minimum slope required for the sewers. Selecting two points as widely separated as is possible without ultimately exceeding the specified depth, or making too long a distance for effective automatic flushing, the sewers generally were run alternately at right angles to, and parallel with, the river, or zig-zag until a junction was effected with a sub-main or main. Special attention was given to provisions to enable the flushing water to traverse the entire length of sewer from the flush tank at its head, without an excessive number of such tanks. Where two sewers change direction through the same manhole the flow of each is directed through curved channels which have no connection with one another; and where they cross one another at different elevations the flow is carried through in separate channels.

This method of alignment results in the sewage being rapidly collected into larger sewers, whose smaller inclination serves to keep them more nearly parallel with the surface, thus not only securing comparatively shallow depths, but enabling the sewage to be transported for long distances before it is discharged into a main collecting sewer. By this method the sewage, in some places, is delivered to a main through a distance of some 9,000 feet, and with a maximum cut of from 10 to 13 feet.

Plates XVI and XVII show the method of alignment as above described in two sections of the city. Plate XVI is the front territory between Louisiana Avenue and Audubon Park, and shows the method of collection from the river back. This is what is termed a "Cut Sheet," and is intended for the benefit of contractors or bidders, having marked on it the average depth of the sewer on each block, from the

surface of the ground to the bottom of the excavation, thus enabling the contractor to tell at a glance the size and depth of any sewer to be constructed.

Plate XVII covers a sparsely built section in the rear of the city, and shows clearly how it is possible with this method of collection to take full advantage of any slight fall in the ground to secure an economical design. This is what is designated as an "Elevation Sheet;" the size and elevation of each sewer at every intersection being given. This sheet is first worked out, and from it the "Cut Sheet." These two sheets represent the general methods employed throughout the whole city.

While no manholes are shown in the alignment they will be placed at each intersection and at each change in grade or direction of the flow. Their omission from the plans is to permit the direction of flow of each sewer to be more readily ascertained by inspection. Flush tanks are located at the head of all laterals, though only those intended for immediate construction are shown.

LATERAL TRANSPORTATION OR MAIN COLLECTION SYSTEM.

Not the least of the problems confronting the Engineering Department in the design of a sewerage system was the lateral transportation of the sewage. The peculiar shape of the built up area of the city, reaching for a great distance parallel with the river, but for the most part extending but a short distance back therefrom, combined with the obvious necessity for the discharge of the sewage below the central portion of the city, demanded a careful and thorough investigation of the various possible plans for the accomplishment of this purpose.

The gravity main was selected as the most durable, efficient, certain and economical of operation. Plate XV is a profile of the front main and other collecting sewers parallel with the river, extending from the upper to the lower city limits, a distance of 56,000 feet. These collecting sewers receive by gravity all the sewage between themselves and the river, and in some cases from considerable areas in the rear, transporting it by the shortest route to the final pumping stations. An examination of the profile will illustrate the slight variation in the elevation of the territory traversed, as well as the benefits derived from such a concentration of flow into a single collecting main as permits of the employment of slight grades, with the resulting light cuts and decreased number of pumping stations, but two intermediate lifts being required in all the territory above St. Ann Street, a distance of 28,000 feet.

These collecting sewers are located as far back from the river as the elevation of entering sub-mains will permit, not only because of the greater area tributary to them by a gravity discharge, but because the length of the sewer to be built is decreased, the depth of excavation, due to lower elevation of the ground, is less, and the disturbance to traffic and damage to property and streets is reduced to a minimum, the heavy work being for the most part through unbuilt or unpaved streets. Into these sections extending further back, towards the Cemetery, Fair Grounds and other localities, main collecting sewers penetrate and transport the sewage from these areas either to one of the front collecting mains or direct to the pumping station.

PUMPING STATIONS.

A first study of the city, taking into consideration the large area to be sewered and the small difference in the elevation of the surface, would naturally lead to the inference that a very large number of small pumping or lift stations would be necessary to secure satisfactory operation without going to excessive depths. That this is not the fact, however, is due both to the method of collection and transportation already outlined, and to the small area where considerable natural slope exists from the river towards the rear. On account of the existence of this natural collecting area, a strip extending along the river from Carrollton to the Barracks, and from 5,000 to 10,000 feet in width, is drained to the collecting sewers without the intervention of any pumping stations, the pumping stations in the line of the main sewers serving only for the lateral transportation to final disposal. Back of this strip, however, where but a slight variation in surface elevation exists, local pumping stations are required to serve relatively small areas, the extent of which are limited either by such natural boundaries as large drainage or navigation canals, or by the limiting depths which have been determined upon. Even in these so-called flat areas small differences of elevation have been used to good effect wherever they existed.

The total number of pumping stations required to serve the entire area is 16, of which 3 are high lift stations discharging through force mains into the river, 3 are intermediate low lifts in the lines of the collecting mains, and the remaining 10 are first lift stations and serve local collecting areas only. Of these, the 3 high lift stations and the 2 low lift stations along the line of the collecting mains, and the 4 first lift stations, are required for immediate construction. Pumping Station "C," located in Algiers, will be operated by steam in connection with the Waterworks plant. Pumping Station "A" will be operated by steam, all other stations being equipped to operate auto-

ically by electricity generated at Pumping Station "A" and dis-
ıted to the various sub-stations through ducts laid in the crown of
ɔrick sewers or in the same trench with, and above, pipe sewers.
The amount of sewage to be discharged by the first lift stations
ually quite small, varying in quantity from 400 to 800 gallons per
ute for the immediate present to an ultimate estimated capacity of
ı 1,000 to 4,500 gallons per minute. Pumping Station "C" is
gned to serve the whole of Algiers, both present and future, with
stimated discharge of 1,500 gallons per minute and an ultimate
harge of 5,000 gallons per minute. Pumping Station "B" will
e all the territory below Lafayette Avenue and back to Florida
k. The greater part of this territory is still unimproved, while
her considerable area is but sparsely built up. The variation,
efore, in the estimated present and ultimate discharge is quite
e, ranging from 2,500 to 13,000 gallons per minute. The Main
ıping Station "A" drains all the territory above Lafayette Ave-
with a present estimated discharge of 26,000 gallons per minute
an ultimate future discharge of 57,000 gallons per minute, or
)0,000 gallons in 24 hours.
All these stations will be equipped with vertical shaft centrifugal
ɔs. The lift at the first lift stations will be constant at each and
ange from 8 to 12 feet. The total lift at Pumping Station "A,"
ding frictional loss, will vary from a minimum of 30 feet to a
mum of 56 feet. The total maximum lift at "B" is 45 feet, and
C" 50 feet.

UNDERGROUND OBSTRUCTIONS.

Iew Orleans is apparently no exception in the matter of under-
d structures and obstructions. Many of these have been laid
lless of any city supervision or regulation, wherever the con-
ing companies have desired, and upon no well-defined plan,
t that of expediency. The aim of all has been apparently
e the most available location and get as near the surface as pos-
regardless of either alignment or grade, and until recently no
s have been kept. While other cities have more and larger
ground structures, few present more complications than New
s, where narrow streets and surface railways cause crowding,
e lack of specific information renders a location for sewers diffi-
Much time was devoted to ascertaining the location and extent
lerground structures existing in the densely built section of the
Plate XVIII illustrates the condition existing at one street
ction. It is one of 250 intersections within what is called the
t area, and shows, in a general way, the difficulties that will
sewerage construction in the business section of the city.

In addition to the private underground obstructions, the extension of the drainage system over a large portion of the city adds to the perplexity of the problem of design and location. The design of the drainage canals, required by local conditions, is such as to prevent sewers from crossing under them in most cases, except at a largely increased depth or by syphon. Usually the large drainage canals form the division line of sewers tributary to the different sub-mains, while the smaller canals are passed under by syphons, in the few cases where this becomes absolutely necessary.

FINALLY.

The City of New Orleans is already of metropolitan proportions, both in population and in area. The topography indicates with almost a certainty, the direction of future growth, and municipal census statistics define, within reasonable limits, even the rate of growth that may be anticipated. The rare opportunity, therefore, existed for the formulation of a sewerage plan complete in every detail, and with every main and sub-main designed with regard to the future work, which it will, sooner or later, be called upon to perform. It has, therefore, been possible to design a system of sewerage in which the construction required for the present is in conformity with a well-defined plan which can be economically filled out to meet the growing needs of the city.

CHAPTER XI.

Water Works Plans.

EXISTING CONDITIONS.

In attempting to treat briefly the general question of a new waterworks system for New Orleans, attention should first be called to the existing status. There are over 350 miles of populated streets, covering about 13 square miles of area, upon which are located 60,000 premises, housing 300,000 people. The existing waterworks system has 135 miles of pipe lines, enters 5,000 premises, and supplies probably about 40,000 people with Mississippi River water and mud. These water mains are themselves so filled with deposit that even upon the rare occasions when the river water is reasonably clear the water from the mains is often just as muddy as at other times. This water, unfiltered, is really unfit for any use except street and lawn sprinkling; and even those who take it depend mainly—for all ordinary uses—upon cypress cisterns built above ground and supplied by rain water caught from the roofs of houses; the remainder of the city depends altogether upon such cisterns. Cisterns, however, often go dry, and great inconvenience is frequently occasioned by the lack of any adequate water supply. The river water should be filtered for drinking, and the cistern water is both boiled and filtered by the cautious. Many people buy table waters at from 8c. to 35c. per gallon, delivered at their homes. The need for an adequate public supply of pure water is, therefore, evident.

TOPOGRAPHY OF COUNTRY ABOUT NEW ORLEANS.

New Orleans is located about 100 miles above the mouth of the Mississippi River, and for this entire distance, as well as for many miles above the city, the river traverses a country of its own construction. Except for the artificial levees which restrain it, the river would overflow its banks at every annual high water. At New Orleans the highest natural ground along the river bank is only about sixteen feet above the level of the Gulf of Mexico, or at elevation 37. C. D., and large portions of the city are at, or below, the level of the Gulf. Plate XIII is a rough contour map of the city; Gulf level being at about elevation 21 of the Cairo datum, upon which the contours, on this map, are based.

Plate XIX shows the general topography of the area covered by it surrounding New Orleans; the shaded area is either Gulf level swamps or lands only a few feet above Gulf level, and so low and flat as to be subject to overflow, either by high Gulf tides or by high waters in the rivers which traverse them. North of the shaded area lies a nearly level sandy pine country, which on its southern edge is not over ten feet above Gulf level, and which rises very gradually to the North.

It will be seen, therefore, that within a distance of over forty miles from New Orleans (by any practicable land route) there is no possibility of impounding water at an elevation of more than twenty feet above tide level; by going twenty miles further north the surface of an impounding reservoir might be 100 feet above tide level, and another 20 miles might gain another 100 feet. Approximate profiles have been prepared in this connection, but are not of sufficient interest to warrant publication.

POSSIBLE SOURCES OF SUPPLY OTHER THAN THE MISSISSIPPI RIVER.

Plate XIX shows all of the possible water sheds, and outlines the routes of pipe lines to reach them. In the upper right-hand corner of the Plate the approximate area and the assumed dry weather run off from each water shed is indicated. It will be seen that most of these water sheds would not furnish a sufficient dry weather flow from which to supply New Orleans without storage reservoirs in which to retain a part of the excess flow which follows storms.

The entire area is sparsely populated; the waters usually are considerably colored, and after storms quite turbid. It is, therefore, evident that filtration would be required in order to guard against pathogenic bacteria, and to remove color and turbidity.

In order to determine whether the questions of storage and filtration need be studied in this connection, Plate XX was prepared, giving the approximate cost of pipe lines and pumping stations to deliver 40,000,000 gallons of water a day to the suction pipe of the distribution pumps in New Orleans, and the approximate cost per annum for water so delivered, including interest on first cost of items included in estimate, depreciation and operating expenses.

It should be said that Plate XX, as originally prepared, had a project No. 6, which was designed to take water from the southeast or city side, of Lake Maurepas. This made a much shorter and cheaper pipe line to the city. Lake Maurepas is a shallow arm of the Gulf of Mexico, and is surrounded by, and drains, great areas of tide level swamps. Two considerable rivers enter it, however, on its north

Table

Project Number.	
1	
2	
3	D.
4	
5	
6	......
7	
8	
9	
10	H.
11	H.

west shore, and these rivers, the Tickfaw and Amite, drain fairly large and desirable water sheds.

In order to get a satisfactory water from Lake Maurepas it would be neccessary to prevent admixture of salt Gulf water and to keep out the swamp drainage; in other words, to build a storage reservoir within the Lake, and to levee one of the rivers to this reservoir.

This would require the pipe line to reach the northwest side of the Lake, and it would, consequently, be but little shorter than that required for project No. 3, while the other attendant expenses would be vastly greater.

It would have been misleading to include project No. 6, as originally given in Plate XX, and it has, therefore, been omitted.

Of the practicable projects, Nos. 3 and 7 are the cheapest, and while No. 3 is slightly more expensive than No. 7, as based upon items considered, its water shed is so much larger that storage would probably not be required at once, and would be less costly when the supply had to be increased; No. 3, therefore, is probably the best project; this would take water from the Tangipahoa River near Ponchatoula by a 48-inch pipe line 46 miles long and parallel with the Illinois Central Railroad. To deliver 40,000,000 gallons a day to a low level reservoir at the city line of New Orleans, through such a pipe against friction, would require a pump lift equal to over 450 feet, made at two pumping stations, each lifting 225 feet. The first cost of the pipe lines and pumping stations would be about $4,000,000, and the cost of the unfiltered water delivered to the suction pipe of the city distribution pumps would be about $20.00 per million gallons.

When the first cost of project No. 3 was considered in connection with the financial resources in the hands of the Sewerage and Water Board, it was evident that this cost was prohibitive if the Board proposed to construct, even most economically, sewers and waterworks systems, including connections to the property line, as the law requires, for the present inhabited area of the city.

By extending the period of construction to December. 1908, the Board can expend on construction work about $10.400,000. Sewers will consume, say, $4,500,000. Water distribution, pipe and pumping system will require at least $3,400,000. Connections to both systems will cost probably not less than $1,500,000, and the $1,000,000 remaining is the maximum amount that can be expended in first cost in bringing a water supply to the suction pipe of the distribution pumps.

A purification plant to handle 40,000,000 gallons of Mississippi River water a day can be constructed at a first cost of less than $1,000,000; and the cost of the filtered water delivered to the suction side of the distribution pumps will not exceed $15 per million gallons.

The supply is unlimited, and the capacity of the plant can be economically increased by small amounts, as the needs of the city increase; an advantage which a distant supply does not possess.

The quality of the Mississippi River water, after the suspended matter is removed, is particularly good, and it is greatly to be preferred to the unfiltered waters from north of Lake Pontchartrain, which would cost over four times as much for construction and 33 per cent more per million gallons of water delivered. Even compared with *filtered* supplies from these local water sheds, which would cost nearly 90 per cent more per million gallons of water delivered, and probably five times as much for construction, the single advantage of these more costly supplies over the filtered Mississippi River water would be that they are softer. In view of these considerations all further study of the supplies from north of Lake Pontchartrain was abandoned.

Artesian sources were considered and abandoned because the quality of local artesian water is not such as would warrant its use; and artesian water from distant sources, while fairly good as to quality, is more than doubtful as to quantity and permanency of supply, and the distance to known sources of fair quality makes the cost of a pipe line to the city prohibitive.

There remained, then, the Mississippi River as the single hopeful source of supply, and all efforts were centered upon the development of a proper system for the purification of its waters. That this could be done successfully was never doubted in view of the light which the Louisville and Cincinnati investigations had thrown upon the quite similar problems presented to those cities.

Coincident with the investigation at Audubon Park, to determine the best *method* of water purification, the general plans for the ultimate waterworks system were in course of preparation. The first question for decision was the vitally important one of how much water per capita should be estimated in this connection.

ASSUMED PER CAPITA WATER CONSUMPTION.

It was, of course, evident that the size and first cost of *all parts, both of the waterworks and sewerage systems*, would depend upon the assumption as to water supply per capita.

It was equally evident that an unusually important list of items of cost of operation would vary with this same factor; this list, including the cost of coagulant, the cost of cleaning the deposit from reservoirs and the cost of the several pumpings, from three to six, required from the time the raw water leaves the Mississippi River, at

the waterworks intake, until it reaches it again as sewage, at the sewer outlet. In deciding this question there is no local experience upon which the judgment can be formed.

If the local waterworks company, which pumps from 300 to 600 gallons per capita of actual consumers, were to be taken as an index of future water consumption, the Sewerage and Water Board could not even consider the question of serving the present population, with the resources at its command. The local company, however, has an unusually large proportion of big consumers, and has suffered greatly both by public and private waste of a liquid which, in its present state, does not command the respect of the community, and cannot be satisfactorily metered. The company also suffers greatly by leakage both from the mains and service pipe of its distribution system; parts of which are very old and defective.

Careful consideration of all of the factors above enumerated, and of the experience of other cities, led finally to the assumption of 160 gallons per capita per diem as the maximum rate of actual pumpage into the distribution system on the hours and days of maximum consumption, and the *average* daily consumption should not exceed one-half of the above amount.

To allow for the loss in capacity with the increasing age of mains, 10 per cent was added to the above stated maximum and the sizes of water mains then computed upon the basis of the capacity of new pipe.

FILTER AND CLEAR WATER RESERVOIR CAPACITY.

For the settling basins and filters it was decided to arrange for the easy treatment of 40,000,000 gallons, and the emergency treatment of 50,000,000 gallons. In order to permit the continuous operation of of the filters at a uniform rate, it was decided to have at least 12,500,000 gallons clear water reservoir capacity to equalize the variation between maximum and minimum hourly rates of consumption.

PROVISION FOR FUTURE GROWTH TO BE MADE IN PRESENT CONSTRUCTION.

It was determined, so far as possible, to so design both sewerage and waterworks systems that no future additions would have to be made to either system on any street now requiring service within the present built-up area, as the population in said area became more dense with the city's growth and development, but either to build now to meet all future demands, or to provide means for the construction of auxiliary feed pipes for the waterworks and relief mains for the sewers through streets in areas now unbuilt, and, therefore, requiring

no present service. Even where the utmost advantage is taken of this latter method of minimizing present construction costs, the present work required to anticipate future growth is considerable. Parts of the city which require service are now quite sparsely populated. The present population of some 300,000 people is spread over about 13 square miles of area and some 350 miles each of sewers and water mains will be required for their service. Ultimately a far larger population will occupy this present built-up area, and at the same time the remaining area which has been included in the present plan will also have become populated, when it is estimated that there will be 23 square miles of area, about 700 miles of streets and 860,000 people.

GENERAL DESCRIPTION OF SYSTEM PROPOSED, AND REASONS GOVERNING DESIGN.

Plate XXIV shows an outline of the plans at present proposed for a waterworks system. The unshaded area on this map represents the present populated area. The hatched area represents the remaining portion of the city, for which plans have been developed.

LOCATION OF PURIFICATION AND PUMPING PLANT.

Upon an examination of the map it will be seen that the following advantages lie with the location of the purification and pumping station site which has been chosen. It lies wholly within the Parish of Orleans, and taps the river at the extreme upper end of said parish. It is, therefore, all within the police jurisdiction of the city, and it obtains its water at the upper city line, above the influence of discharge from shipping, and very far above any sewage outlet.

From this point of intake, or from any other point of intake higher up the river that may for any future reason be found desirable, or from any practicable distant source of supply, even, this location is in the line of shortest distance to the center of population of the city, and practically for all parts of the city.

It is 3,800 feet back from the river bank, and, therefore, safe from the effects of caving banks, yet close enough to permit of the construction of a level suction line below low water level in the river, which can be operated by pumps located at the station, containing all other pumps required for the operation of the works. The friction loss in this length of suction line will be well within the suction capacity of the pumps, and the fact that for this distance a level line can be obtained, in which no air pockets can form to interfere with operation, permits this arrangement. At no other point in the upper part of the city can an equal available area be found nearly

so close to the river bank, and nowhere else would a level suction line to an available open area be possible, without seriously cutting into existing drainage canals and proposed sewers, and even here it could not be carried further back for the same reasons.

We have, therefore, the only point where all pumping can be done under one roof and by one set of boilers, which is clearly a great advantage in cost, both of construction and operation, as well as in simplicity and certainty of uninterrupted service. From the point of view of basin cleaning we have available the short return line to the river, which will undoubtedly be the cheapest ultimate way of disposing of the accumulated deposits; these deposits from 40,000,000 gallons of water a day will amount to something over 50,000 cart loads a year, or enough to fill an average city square 12 feet deep. So far as possible this material could be given to anyone who would care to haul it away for lot filling, or could be pumped out on such low ground as might be available. Very long pipe lines, however, would be necessary to reach large areas of low unimproved property where such filling would be desired, and unless the owners of such property will join in the cost of pipe lines and extra pumping expenses to this end, which is not likely, the Sewerage and Water Board will soon be under the necessity of returning this material to the river, and will be in a good position to accomplish this economically.

AREA AND CONDITION OF GROUND TO BE ACQUIRED.

The proposed purification station site comprises 26 squares, or 68 acres of ground; a considerable portion of it is at present open ground and covered with a luxuriant growth of weeds; some of it, however, is devoted to market gardening; some to dairies and a very small portion has been subdivided into small lots, part of which have been sold and built upon.

In 1900, when its acquirement was first recommended, its total assessed valuation upon which taxes were paid was under $17,000.

RELATION OF LOCATION CHOSEN TO DISTRIBUTION SYSTEM.

At first glance, perhaps, a location for distribution pumps at what appears to be one end of the city would seem of rather doubtful advantage. It was concluded in the beginning, however, that water should be taken from the river at or above the upper city limits, and any other location for distribution pumps would require the return of purified water for considerable areas over the route by which it had been brought from the river. With the present plan every motion of the water from the time it leaves the river, except for about 1,200 feet

from the first low lift pumps to the back end of the plain subsiding reservoirs, is towards, and on the shortest possible line to, the center of population to be served, and nearly always on the shortest possible line to any and all population to be served.

The low lift pumps, which have a comparatively high cost of operation in proportion to the work which they perform, do a very small part of the work, and the more economical high lift pumps take up the work at the earliest possible moment.

The relative position of this purification station site to the present populated area of the city is such that the shortest main line of distribution pipe to the heart of the city traverses the rear lines of the present built-up area, thus serving its present population, and, as areas back of this are improved and require water facilities, each pipe line laid through said areas will also serve to reinforce the central area of the city by a line as short as the original main line, thus supplying the center of the city fully after the original line has become inadequate, because of increased demands upon it both by the area through which it passes and also by the center of the city. No other possible pumping station site offers this opportunity for gradual extension on advantageous lines throughout new and developing territory to meet the growing needs of the whole city, without paralelling existing lines of pipe and working over areas in which the inconvenience of such construction has already been suffered. The above considerations having determined the site of the purification and pumping station, the design of the distribution system leading from it remained for consideration.

In this design three main points for consideration had to be borne in mind as follows:

1st. Present needs must be served at the least possible first cost for construction, consistent with the permanent usefulness of all work done.

2nd. The present system must be so designed as to permit of the most advantageous use of the mains of the existing waterworks company, should these be acquired, or of a new construction over the area which they occupy, in the event of their non-acquirement.

3rd. Present work must fit into and form a complete and useful part within the area which it covers, of an ultimate system which will serve nearly twice as great an area, and about three times the present population.

WORKING HEAD.

The most distant points will be about 50,000 feet from the distribution pumps ; these pumps will work under a 200 foot head, and the

design of the distribution system is based upon an available head, at all points, of not less than 100 feet at maximum discharge. There are no high points upon which equalizing reservoirs to give this head can be located, and the large consumption does not permit of the consideration of stand-pipes to accomplish this result, because their height, diameter and difficulty of foundation, to render them even moderately effective in equalizing pressure, would be beyond possible consideration in cost.

DIRECT PRESSURE SYSTEM ADOPTED.

The remaining alternative, therefore, has been adopted, i. e., direct pressure with balanced relief valves, permitting discharge into the low level clear water reservoirs, and possibly at other points, for the relief of any excessive and sudden pressure tending to destructive water hammer.

HYDRAULIC GRADIENTS.

With 50,000 feet as the maximum transmission of pressure, and 100 feet of head to expend in frictional losses, only two feet per 1,000 can be given to hydraulic gradient on main lines supplying such distant points, and the system proposed for the present is designed to serve the present population with this unusually low hydraulic gradient.

In the design of the ultimate system, however, the city was divided into three areas: the first of which had no point more distant than 25,000 feet from the pumping station ; the second none more than 33,000 feet ; and the third, or distant area, having a maximum distance of 50,000 feet. Provision was then made to entirely divide these areas, if necessary.

In the first area a hydraulic gradient of four feet per 1,000 at maximum discharge has been assumed ; in the second, three feet, and in the third, two feet. In this way it has been possible to design a far more economical ultimate distribution system than could otherwise have been done, and the control of waste and the arrangement of pumping and valve manipulation for the equalization of pressures in various parts of the city will be practicable within closer limits than could be accomplished were the ultimate system to be operated as a whole.

RE-WORKINGS OF DESIGN FOR DISTRIBUTION SYSTEM.

It is hardly necessary to say that a number of re-workings of the distribution system were necessary before the three rather irreconcilable objects previously outlined were nearly met and reconciled in one

single plan. The past in the shape of an existing distribution system, shown in dotted lines on Plate XXIV, and which had to be fed from its little end, persisted in such sins of omission and commission, both major and minor, as were the despair of those who were attempting to design a regular and systematic system. The present, with strictly limited resources, must not only purchase the sacrificial goat which shall atone for all these sins of the past and attend to its own needs, which are great, but it must also listen to the voice of the future, which kept insisting upon the wisdom and expediency of doing all kinds of impossible and extravagant things in its interest.

LABOR-SAVING DEVICES USED IN DESIGN.

The numerous re-workings of the plan and of comparative estimates looking to the harmonization of these conflicting interests were greatly facilitated by all possible labor-saving devices and short cuts for quick computations. A large number of diagrams, tabulations and specially constructed scales, reducing the number of operations leading to desired results, and consequently the probability of error in said results, were carefully devised and prepared both for designing sewers and waterworks: The several re-workings required for both systems, and the very large area to be worked over made the use of such methods of work an actual necessity, and by them an immense amount of time was saved, and the labor of re-working reduced sufficiently so that it could be done again and again so long as need for so doing was apparent.

As an illustration of these time saving methods the writer would cite the series of scales which were prepared to conform with the scale of the map used, and with the various rates of population per given area which were assumed as the ultimate density of population in various areas. By taking one of these scales and applying it to two sides of any rectangle in the area for which it was designed the product of measurements so derived gave directly the maximum rate of water consumption to be estimated for said rectangle, in million gallons per 24 hours. Thus by two measurements, and a mental or slide rule multiplication, all in easy numbers, in which a serious error was impossible, there was obtained the same result which would ordinarily be derived from two measurements in scale of feet followed by four long multiplications or divisions in which, when unchecked, the opportunity for error was very considerable.

HYDRANT, VALVE AND MINOR PIPING ARRANGEMENT.

Plate XXV shows a sample of the general arrangement of the minor piping and of valves and hydrants which is contemplated. It is

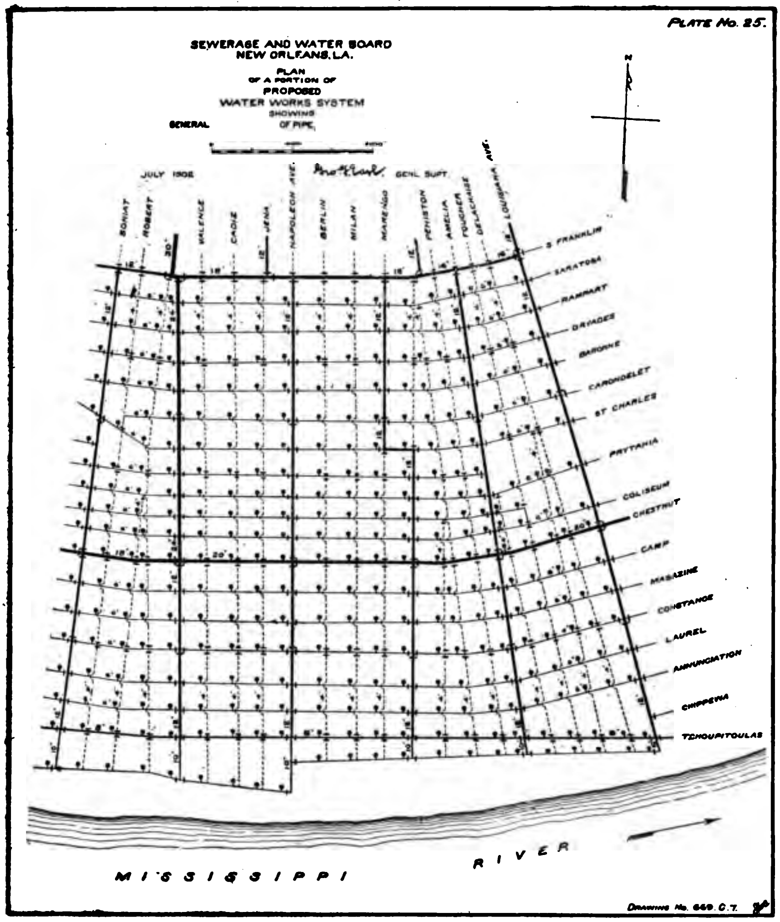


PLATE No. 25.
SEWERAGE AND WATER BOARD
NEW ORLEANS, LA.
PLAN
OF A PORTION OF
PROPOSED
WATER WORKS SYSTEM
SHOWING
GENERAL
OF PIPE
JULY 1906
GEN'L SUPT.
SONIAT
ROBERT
VALENCE
CADIZ
JENA
NAPOLEON AVE.
BERLIN
MILAN
MARENGO
PENISTON
AMELIA
FOUCHER
DELACHAISE
LOUISIANA AVE.
S. FRANKLIN
SARATOGA
RAMPART
DRYADES
BARONNE
CARONDELET
ST. CHARLES
PRYTANIA
COLISEUM
CHESTNUT
CAMP
MAGAZINE
CONSTANCE
LAUREL
ANNUNCIATION
CHIPPEWA
TCHOUPITOULAS
MISSISSIPPI RIVER
N

fully realized that a system of piping, in which no pipe is less than six inches in diameter, is a very desirable thing to have, and that the cross connection of all pipe at every street intersection, with two valves at each intersection, placed in such form that four valves will always cut out two blocks of pipe, is also an admirable arrangement. It is believed, however, that, so long as all pipe supplying fire hydrants is at least six inches in diameter, not over 1,200 feet long, and supplied from both ends by pipe of sufficient capacity, the fire supply will be ample; and there seems no reason to doubt that a four-inch pipe of the same length, and properly connected with larger pipe at each end, will ever lack circulation or fail in any way in domestic service, and the saving in fittings and valves, and in reduced size of pipe, is a very considerable amount, which it appears can be more judiciously expended in other directions.

The small map, Plate XXIV, of distribution system shows only the general outlines of said system; pipe smaller than 12 inches is usually not shown on it; and these, of course, will constitute by far the greater part of the system. As the plans are drawn there will be no dead ends anywhere; but every part will permit a free circulation, and all minor pipe lines will be in short lengths and supplied from both ends.

INTAKE, PUMPING AND PURIFICATION SYSTEM.

The pumping and purification system proposed has its location with reference to the ultimate distribution system indicated on Plate XXIV. All of its parts, and their relation one with another, are shown in plan in Plate XXI. Plate XXII shows to larger scale and more in detail the general arrangement of the pumping and purification system, and Plate XXIII shows to a natural scale a profile or section of the line of water passage from the river to the clear water reservoirs. Following through Plates XXI, XXII and XXIII in the order of water passage, the writer will try to give briefly the main controlling reasons for the chief features of the design as proposed.

LOCATION OF INTAKE.

It will be seen that the intake is located at the low water shore line of the river, and is a very cheap and simple structure of piles and sheet piling, arranged always to take water from very close to the fluctuating river surface, and to deliver it through a level suction line laid below low water level to the first low lift pumps. The Mississippi River at New Orleans is usually a disappointment to visitors who see it for the first time, and have before seen it higher in its course. Its width here is usually less than one-half mile, and there is nothing to

indicate its depth. In this latter dimension, however, at New Orleans, and indeed from far above New Orleans to the Passes, the deficiency in width is fully compensated. There is no cross-section of the river opposite New Orleans which does not reach a depth of at least 80 feet, and at the deepest point the depth is 190 feet, all at low water, which is Gulf level.

The point of greatest depth in any section of the stream is governed by the line of the strongest river current; this does not follow the center of the stream, but crosses from side to side, approaching and tending to cut away more and more the concave bends of the river — the banks of which are consequently known as "caving banks"—while lower current velocities continually permit the deposits of material on the opposite side of the river, thus building it out and forming a "making bank," and maintaining a uniform, though shifting, cross section, which complies with the natural balance of things required for the equilibrium of the mighty forces at work. The proposed intake for New Orleans is on a caving bank. The slope of the bank at this point below the low water level of the river is very steep, reaching a depth of 80 feet, 130 feet from said shore line; and a depth of 120 feet, 280 feet from said shore line; a little further out the maximum of 131 feet is reached, after which the depth decreases gradually to the opposite shore. These depths are measured from low water, and the elevation of the high water surface of the river is about 20 feet above low water level. The whole bed of the river, as well as the whole area of the city for a depth of hundreds of feet, is in an alluvial formation, varying from pure soft clay to sandy clay; to fine and then to coarse sand in perfectly irregular strata, about 10 feet, from the Gulf level down, is often full of stumps, roots, etc., and peaty formations are often found still deeper. It is, therefore, evident that any structure built upon a river bank of this character can be only as permanent as the bank itself, upon which it stands, and since the history of this particular bank indicates a recession of about 600 feet in 70 years, there has been no effort to design a permanent structure at the intake. The United States Government contemplates bank protection or mattress work at this bend, and has done some already, and it is to be hoped will eventually secure it from further erosion. The arrangement at the Waterworks intake to take water always from near the surface of the river is in order to get that water in which there is the least suspended matter, and our own investigations, as well as many other records, indicate that there is always a marked increase in the amount of suspended matter as the depth from the surface increases.

MAIN SUCTION LINE AND RAW WATER PUMPS.

From the point of intake 48-inch cast iron pipe lines will lead by the nearest route to the first low lift pumps (see Plate XXI). One such line can serve the present built up area, but two will be laid if funds will permit, because of the danger of accident and interruption of service incident to a single line. This will be ordinary lead jointed pipe with pile or other secure foundation near the low water river bank; where it passes through the levee light cut off walls will be constructed to prevent percolation along the outside of the pipe line at high water. This suction pipe will be level, and even at extreme low water will always be ready primed for pumping; its top will be over a foot below the lowest known water. At ordinary elevation of the river the lift into the settling reservoirs will be very small, and at high water the first low lift pumps can be entirely by-passed and the water drawn at will into the reservoir.

SEDIMENTATION RESERVOIR SYSTEM.

Leaving the first low lift pumps the water will pass into a conduit in the walls of the reservoirs through which it can be led in any desired direction at will; in ordinary operation it will pass to the back end of the reservoir system, and be discharged through a number of small openings in the bottom of the rear wall, and at the bottom of the plain subsidence reservoir, which latter will hold about 23,000,000 gallons of water. The passage of the water through this reservoir will occupy at least 12 hours, and in passing it will be so baffled as to compel effective displacement; probably two lines of vertical baffles, arranged to draw water from their top on one side and force its passage to the bottom of the next sub-division of the reservoir, will best accomplish this displacement. At the front end of the plain subsidence reservoir a line of skimming weirs will deliver the water into a collecting conduit in the wall between the plain subsidence and coagulating reservoir, which will in turn deliver it to the coagulating well in the middle of this wall. By this time all of the suspended matter which can be economically removed by plain subsidence will have been eliminated, and the addition of coagulant will, therefore, be in order. At the coagulating well, as in fact throughout the whole system, there will be passing a very large and perfectly uniform flow of water, containing still innumerable fine clay particles in suspension, which no amount of plain subsidence can successfully remove, and no known method of filtration can dispose of in a sufficiently economical manner to even warrant consideration, as applied to a city waterworks system.

COAGULATION.

In order to bring these clay particles together a very small stream of a 5 per cent solution of sulphate of alumina will be added, thoroughly mixed with the great volume of water, and the whole discharged through a distributing conduit, parallel with the collecting conduit above mentioned. Passing through small port holes in the bottom of the distributing conduit, the water will receive again exactly the same treatment which it received in the plain subsidence reservoir; only now, due to the fact that the clay particles have been brought together into ponderable masses, they will find it less easy to pass baffles, to float and sink and float again with the water in which they have moved so long that they have become almost a very part of it.

Under average conditions 65 per cent of these particles of suspended matter will succeed in passing through the plain subsidence reservoirs; after coagulation only about 7 per cent will be able to effect a similar passage through the coagulating reservoir, and even these a little more coagulant or little more time would vanquish. It is cheaper and better, however, to deal with these last remnants of turbidity at the filters; even those particles of suspended matter which succeed in passing the final skimming weir, and entering the conduit which leads to the filters, have been so aggregated and prepared for filtration that they cannot, as they would before such treatment, pass through the sand layer of the filter. The passage to and through the filters from the coagulating reservoirs is still by gravity; the water standing at nearly the same level in the settling basins and over the filters. The rate of passage through the filters is regulated so that it cannot exceed a certain given and perfectly uniform rate, regardless of the rate of pumpage into the reservoirs. If water is pumped into the reservoirs faster than the filters can handle it the reservoirs will be filled to the level at which they will overflow and waste, and an alarm in the pumping station will sound, and the rate of pumping will be decreased. When any filter becomes so clogged with suspended matter that it cannot pass water at the required rate an alarm will note the fact, and that filter will be cut out of service and washed by passing a very strong current of filtered water, and of air, if necessary, through it in the opposite direction to that in which it usually operates. This causes the sand to boil up, and floats out the matter which has been caught by the sand layer. The operation of washing will be necessary from once to twice each day, consuming about eight minutes for each washing. About 3 per cent of the water filtered will be required for washing the filters.

OPERATION OF PUMPS AND CLEAR WATER RESERVOIRS.

After passing through the filters the water enters a small equalizing clear water reservoir immediately beneath them, from which it flows through a gravity conduit to a pump-well connected with the same pumping station through which it passed as raw river water about 24 hours earlier, having returned to this point by gravity and having dropped 15 feet in its passage. From this clear water pump-well, so far as possible, the water will be taken directly by the distribution pumps and put under exactly the same pressure in the city mains as said mains would carry were they fed by a reservoir whose water level was 200 feet above the level of the city. If we had such a reservoir of sufficient capacity the distribution pumps could work at a constant rate against a perfectly uniform pressure, and just as the filters delivered the water. Not having it the distribution pumps will not take as much water as the filters will furnish at night, and at certain hours in the day they will require quantities of water vastly in excess of that being furnished by the filters. It is neither wise, safe nor economical to attempt to filter water just as it is needed, and, therefore, clear water reservoirs are provided holding something over 12,000,000 gallons; a second set of low lift pumps being installed which can take the surplus water from the filters during hours of low consumption, and raise it into these clear water reservoirs, to be drawn upon as required during hours of high consumption.

Every foot of lift made by the second low lift pumps saves a foot that would otherwise have to be made by the high lift pumps; but since the first named pumps will work with a far lower efficiency than the last named, it is desirable to do the least possible amount of work with the least efficient machine, and the equalizing clear water reservoirs beneath the filters will greatly aid to this end.

The first intention was to pass all water through the second low lift pumps to and through the clear water reservoirs. This would have been more economical than the construction of a sufficiently deep and capacious clear water equalizing basin, if the construction of such a basin served no other end. In studying out the question of a filter foundation, however, it finally became evident that such a basin beneath the filters would add almost nothing to their cost, and much to their accessibility, and at the same time would eliminate the greater part of the second low lift pumping and add to the certainty of continuous operation. For emergency conditions, to meet contingencies which are never expected to arise, but which, should they happen during a conflagration, might be immensely costly, the following by-passes and cross connections have been made:

First, the second low lift pumps can be connected with the suction main from the river and deliver water into the raw water reservoirs.

Second, the filters can be by-passed so that settled water can be sent direct to the distributing pumps.

Third, the settling reservoirs can be by-passed and the water sent direct to the filters via low lift pumps, or direct to the distribution system via distribution pumps.

Every reasonable precaution has been taken to prevent the necessity for the use of any of these expedients, but should such necessity arise, the failure to have provided for it would be inexcusable when the provision is so easily made.

METHOD OF CONSTRUCTING RESERVOIRS.

The questions of the depth of reservoirs, and the method of foundations and class of reservoir construction to be used, have been given very careful consideration. The bearing power of the natural soil of New Orleans is usually taken at not over 1,000 pounds per square foot, and pile foundations are the only method available where heavier weights are to be imposed. This fact led to the general conclusion that shallow reservoirs, with light wall or embankment constructions, could alone be safely considered. The necessity for very large conduits parallel with all reservoir walls, and the great space occupied by earth embankments, finally led to the adoption of a masonry wall, with a conduit or water passage inside of it; to be built of concrete steel construction, with shallow wing or spread foundations, which would not only add weight to the wall and increase its stability, but would also act as part of the reservoir lining. The conduit which such a wall replaces would itself cost a great part of what the wall will cost. The space saved as compared with earth, the difficulty of finding earth of proper quality, or even of finding enough earth at all, without leaving unsightly and objectionable holes on the Board's property required for future construction, the advantage of nearly vertical walls, where part of them must be shaded to prevent the development of Algæ growth in the clearer waters after coagulation; and part entirely covered where, after filtration, the perfectly clear water would rapidly induce such growths if exposed to the light. All of these were important considerations leading to the adoption of the masonry walls as above noted.

PLAN FOR FILTERS.

The plan for filters in size and general arrangement of filters is modeled somewhat after the filter plant which has lately been constructed at Little Falls, N. J. The widely different conditions, how-

ever, render necessary a quite different treatment of the detail throughout. The structure will be founded on piles, with their cut off some ten feet below the ground level. This is also below ground water level, and under drainage and substantial construction will be necessary for the floor of the equalizing clear water reservoir at this level. From this floor will spring the piers and walls which will carry the filters; all of which are intended to be of concrete steel construction, which seems best adapted to the local conditions. A gallery, containing the filter pipe system and valves, etc., for the operation of the filters, will pass between the line of filters and terminate in the office and laboratory building in front of same. In this building the necessary determinations as to the operation of the filters will be made, and the addition of coagulant to the water will be regulated.

HANDLING OF COAGULANT.

Something like an average of 12 tons of coagulant per day will be required for the treatment of 40,000,000 gallons of water, and it is intended to bring this coagulant by ship load lots, to land it at the wharf which will be constructed at the water works intake, to unload it by mechanical means at this point into cars that will be operated by a cable, and will deliver their loads into a storage bin located near the river as shown on Plate XXI; from this storage bin a mechanical conveyor will deliver the coagulant into a service bin holding several days' supply, from which it will be drawn as needed. Four mixing tanks beneath this service bin will be used for preparing dilute solutions of coagulant of known and constant strength. The dry coagulant will be weighed into these mixing bins and dissolved by admitting the proper quantity of water under pressure from below the coagulant; further agitation, if required, to keep the mixture uniform, will be accomplished by the introduction of air at the bottom of the mixing tanks. Proper valve arrangements will permit any or all of these tanks to be connected with a pipe line leading back to the laboratory building, and connecting with elevated tanks through a ball-cock device which will maintain a constant level in said tanks; the outlet of these tanks will consist of a large number of standard orifices which will each discharge a definite amount of coagulant solution, and the amount used will be regulated by the number of orifices open. These orifices will discharge freely into a trough, which will lead into the pipe line to the coagulating well, and the elevation of the mixing tanks near the river bank is such that this entire operation can be accomplished without any pumping of the coagulant solution. The attendant at the coagulant mixing house will refill the mixing tanks with the standard

solution, and see to it that the pipe line to the laboratory is always connected with an ample supply.

At the laboratory skilled supervision will regulate the proportionate amount of this standard solution to be added to the water; this regulation being based upon a constant inspection of the resulting effluent, and upon chemical and biological examinations of the water at all of its stages.

CLEANING SYSTEM FOR RESERVOIRS.

The cleaning of the reservoirs will probably be effected by means of an electrically operated suction dredge, working every day, which will permit absolutely continuous operation of all of the reservoirs. Besides this there will probably be installed an emergency pump and piping system, which will connect with a sump at the lowest point of each settling or coagulating reservoir, through which the reservoirs can be drained, and to which the mud can be flushed and pushed. It has been found that the deposits from the Mississippi River water in the reservoirs will remain in a semi-fluid condition even after several months of operation, and can be easily handled as above described with the wastage of comparatively slight amounts of water.

PROVISION FOR EXTENSION.

Plate XXII shows the provision that has been made for the future growth of the city. Pumping stations, boiler house, filters and reservoirs, can all be extended as the need for such extensions may arise, until the capacity of the plant now proposed has been more than doubled.

SEPARATE PLANT REQUIRED FOR ALGIERS.

In the above no mention has been made of the small purification and pumping plant which must be constructed for the Fifth Municipal District, or Algiers.

This plant will have to be a duplicate, on a small scale, of the proposed plant for New Orleans.

The location for it has been chosen so that the sewerage pumping station and the water purification and pumping station can both be run by the same set of boilers.

This location, as shown on Plate XIII, being just back of the present built up area, will serve it economically both for sewerage and water supply, and will fit well into, and use, an existing water distribution system, should the Board acquire said system. At the same time it will permit of economical extensions of both systems as growth beyond

the present built up area in this part of the city requires them. Three or four squares of ground in this locality will certainly serve all future needs, and these will be acquired in the near future. A single square, most of which has already been acquired, will accommodate the plant required to serve the present population.

PRESENT STATUS OF WATER PURIFICATION DESIGN.

While designs for water purification systems, both for New Orleans and Algiers, have been worked out, as above outlined, they are as yet purely tentative.

In connection with the details of such designs, and especially of the filters, plants now under construction, as at Louisville, or just going into operation, as at Little Falls, New Jersey, may yield valuable lessons, and dictate important changes from the preliminary studies now under consideration. The rapid development of the whole field of water purification, which the past few years has brought, renders a successful solution certain; but its very progress also warns us to watch every detail for further possible improvements looking to decreased costs of construction, or to simplicity and economy of operation. A slight further delay, then, that will give New Orleans the benefit of the experience which may be gained at these new plants, may bring very considerable advantage. Plates XXVI and XXVII will give a general idea of the plan as now contemplated for filter construction.

CHAPTER XII.

COST OF PLANS, FUTURE EXTENSIONS OF SEWERAGE AND WATER-WORKS SYSTEMS, AND THE OPERATION OF SAID SYSTEMS.

COST OF PLANS, ETC., TO DATE FOR WATER AND SEWERAGE SYSTEMS.

Tabulated Showing of Expenditures by the Sewerage and Water Board from Date of Organization, January, 1900, to Date, December 31st, 1902.

SALARIES.

General Superintendent and office force under him, including all costs of sewer investigation, physical surveys and borings		$ 57,526.53
Salaries for Water Purification Investigation		8,140.41*
Salaries of Board of Advisory Engineers		16,391.56
Salaries of Secretary and Chief Clerk	$8,570.65	
Salaries of Janitors	1,410.00	
Salaries of Attorneys	7,752.86	17,733.51
Total salaries, including all expenses for sewer investigation, physical surveys, tests, borings and sundry engineering work		$ 99,792.01

OTHER EXPENSES.

Water Purification Investigation Plant, apparatus disposed of after investigation and supplies, (exclusive of salaries)	13,128.08†
Sundry Expenses—Rent, $1,760.65; telephone service, $322.20; stationery, printing, etc., $2,595.58; miscellaneous office expenses, $2,120.56; balance court costs, $37.80; transfer laboratory, $643.71; laboratory expenses, $512.56; premium on bond of Secretary, $12.50	9,178.55
Total executive, engineering and legal expenditures	$122,098.64

* Including salaries subsequent to October 1st, 1901.

† Balance after deducting amounts received from sale of such parts of plants as were of no further use.

Amount brought forward	$122,098.64

OTHER EXPENDITURES IN THE NATURE OF ASSETS FOR OFFICE AND LABORATORY OUTFIT.

Laboratory fixtures and supplies retained	2,351.62
Furniture and fixtures—Office	3,254.56
Grand Total, office and engineering expenditures	$127,704.82

FUTURE EXTENSIONS OF SEWERAGE AND WATERWORKS SYSTEMS.

As has been said in connection with the sewerage plans, New Orleans is already a large city, both in population and in area. The topographical and other conditions of the country surrounding it are such as to preclude much development outside of the area which is already within the municipal limits, on account of the great cost of levee protection, drainage and other improvements essential to such development. It is, therefore, practically certain that the growth of the city for years to come will be along the lines of least resistance, i. e., in a thickening of population within the present built up area, and a gradual extension into that portion of the now unbuilt area which is covered by the sewerage and waterworks plans, as indicated respectively on Plates XIII and XXIV, and which is already within the zone of effective drainage and rapid transit facilities, close to the business section of the city, and in every way best fitted for early development.

The rate of future growth is not so well defined. In the decade just past the increase of population, according to the United States Census, was about 19 per cent. The improvements to be constructed by the Sewerage and Water Board, and the general awakening of business men, both in New Orleans and elsewhere, to the vast opportuties for profitable development which the city presents, will almost certainly accelerate this rate of growth. During the last decade the average growth of 44 American cities of over 100,000 population has been about 42 per cent. Assuming even a 30 per cent average rate of growth per decade, the area now under consideration would contain 860,000 people by 1942, and there appears every probability that at least this growth will come, and with the growth must also come a greatly increased assessed valuation, upon which the aggregate revenue available for sewerage and water construction cannot possibly fail to fully cover all needs for extensions. That the annual revenue available for extensions in the early life of the Board, however, will be adequate to keep pace with a scattering growth is not so certain, and in designing the work for immediate construction every possible effort

has been made to put it into such form as will facilitate this very essential end.

PRECAUTIONS ESSENTIAL TO THE SUCCESSFUL CONSTRUCTION AND OPERATION OF SEWERAGE AND WATERWORKS SYSTEMS.

In conclusion, there are three points upon which too strong a statement cannot be made :

First—The plans as drawn have been very carefully worked out to satisfy and meet a very wide range of considerations, many parts are interdependent, and what might at first sight appear to be an unimportant departure from them may easily be found later to have a far reaching or even a disastrous effect. That these plans cannot yet be improved by minor changes, or that they will ultimately be constructed exactly as they now stand, is not at all to be supposed; changing conditions must dictate some minor changes in plans to meet them, but such changes as may become necessary should only be made after an exhaustive study of their whole possible effect. It will not do to evade some considerable difficulty one year and thereby destroy the integrity of the ultimate plan or create a much worse difficulty, or even an impossibility a year or so to come, and any purely temporizing managment will be certain to do so.

Second—The works called for in these plans can be constructed so that they may be easily and successfully operated. A little carelessness or inefficiency in construction, however, will be found to have a very serious effect. The difference in cost between good work and bad is not 5 per cent; the difference in result in operation is that between low and high costs for operation, and often between success and failure.

Third—Assuming that the Sewerage and Water Board has succeeded in the construction of the best possible systems of sewerage and waterworks, susceptible in the hands of faithful and competent employees of a highly satisfactory and economical operation, it must yet be remembered that these systems, under less competent or faithful management, can easily give far different results. The proverbial "stitch in time" must be taken whenever it is necessary. The men in charge must understand exactly what they are doing, never hesitating to spend a dollar where it ts needed or failing to save one where exact and careful management can safely do so, if the best results at the least cost are to be obtained.

In order to prevent the waste of water a rigid law governing public waste and house plumbing, and an effective and uniform enforcement of that law, will be essential. Without such laws, and an enforcement of them, coal and coagulant bills will be excessive; and at an early date pumping machinery and reservoir capacity will have

to be increased, and a little later water mains will be short on pressure and sewers overcharged. Competent inspection of house drainage work is also essential; the small drainage pipe which leads from the back of each house to the sewer connection at the property line especially needs to be smooth inside, well laid and true to line and grade, if the annoyance of continual stoppages in it is to be avoided. With proper construction and fair use even these lines will give no trouble; but in this case such construction and operation will require great vigilance upon the part of competent inspectors.

Exact plans and records of all work done, both in construction of sewers and of water mains, and of connections to them, and in house plumbing, must be in the hands of the Sewerage and Water Board, and so indexed and arranged as to be easily accessible for the recording of changes or the looking up of trouble. These plans should show the location, elevation and method of construction of any and every part of both systems, from the waterworks intake to the sewer outlets, including house plumbing arrangements, if these works are to be operated to the best advantage.

The success of municipal ownership and management of public utilities depends altogether upon the faithfulness and efficiency displayed in the small details of construction and operation. Every piece of faulty construction, and every error and omission in the records, or failure to provide and enforce the proper regulations in operation, will cause a certain amount of trouble and cost a certain amount of money.

Since the water purification investigation there remains no part of either system with regard to which there can be any possible doubt as to the result of proper operation, both as to efficiency and economy. Everything has been proven by practical operation here or elsewhere. The only experiment in all that is proposed is inherent in the local situation, and it remains to be seen what result can be achieved in this introduction into a large city, and upon a large scale, of facilities with the use of which a very large proportion of the population is totally unfamiliar. Patient and persistent effort on the part of the Sewerage and Water Board and its employees, and of those who are charged wtth the inspection and control of plumbing regulations, and the execution of plumbing work, as well as the co-operation of the press, and of all citizens who realize the necessity and magnitude of the work to be done, can finally meet even this difficulty, and accomplish for New Orleans an inestimable good in the proper and successful use of the proposed systems.

Respectfully submitted,

GEO. G. EARL,

General Superintendent.

INDEX.

INDEX

TO

DESCRIPTION OF PLANS PROPOSED

FOR

SEWERAGE AND WATER WORKS SYSTEMS

CHAPTERS X TO XII.

For Index to Water Purification Report, see pages 253 to 266.

INDEX

TO

WATER PURIFICATION REPORT.

CHAPTERS I TO IX.

For Index to Description of Plans Proposed, see pages 251 to 252.